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# MACHINE DESIGN

*September 1953*

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THE PROFESSIONAL JOURNAL
FOR ENGINEERS AND DESIGNERS

# MACHINE DESIGN

September, 1953
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# Over the Board

### Just Moments?

For years we have accepted "Moments of Inertia" as an engineering term and thought it was a natural title for last month's engineering data sheet. But to a colleague in our business department the term means something totally different. His comment on seeing the title: "In *our* business we have hours, days and weeks thereof. But we'll live longer, I hope!"

### Fountain of Youth

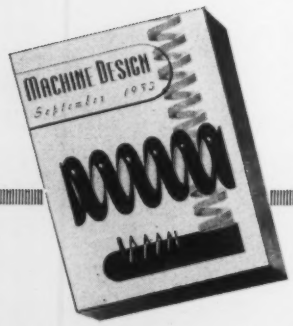
As we all know, there is no substitute for the good old hardheaded brand of common sense when it comes to sound engineering analysis. As earthbound mortals we may find though that these straightforward principles will have to be abandoned when we take our next flight into space. While we don't pretend to be able to fathom the mysteries of the Theory of Relativity, as it applies to our familiar concepts of speed, time, etc., a discussion in the Journal of the British Interplanetary Society clarifies the problem of how to grow old gracefully: "The fact that it is theoretically possible to travel at nearly the speed of light and then return to one's point of origin thousands of years later, having aged only a few years oneself, is just one of those things that must be accepted unless you can follow the mathematics of the Theory of Relativity! The effect has been experimentally demonstrated in cosmic ray studies, so it's not merely something that the mathematicians have worked out on paper! Personally, I don't see why it should be a bigger paradox than the fact arising from the same theory, that matter can be converted into energy. And that is something that few people will deny today!"

### Contemporary Design

One of our most popular features is the Contemporary Design section in which are displayed machines typical of the designs executed by your contemporaries. The short articles are intended to help you keep abreast of design techniques in the whole field of machine design. Hitherto we have presented these articles on consecutive pages, but beginning with this issue we shall distribute them throughout the main editorial section. Our reason for so doing is purely practical: We can use the Contemporary Design articles to simplify the job of laying out our pages, permitting separation of major articles which might conflict through backing up of last and first pages. Such conflicts in the past have automatically cut in half the available supply of clip sheets of certain articles which we can furnish through our postcard service (Page 177).

### This Month's Cover

With Stanley Albright's three-part article on designing springs for lower cost beginning in this issue, it seemed highly appropriate to use this versatile machine element as the basis for a cover design. George Farnsworth has arranged a selection of springs in a novel design which we hope you will like.





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MACHINE DESIGN
SEPTEMBER 1953

# Cutting Costs—Interest or Enthusiasm?

ALWAYS a primary factor in engineering design, costs today loom larger in importance than ever before. In a recent MACHINE DESIGN survey of current design changes, cost reduction was given as the principal reason for change by three-fourths of those questioned. Cost reduction also has been consistently reported to us as the No. 1 problem in the minds of design engineers, in our continuing study of reader problems.

Because the greatest potentials for cutting manufacturing costs lie in the hands of design engineers, management has a very vital interest in their efforts and should employ every possible means to aid them. Too often the decree goes out "Cut costs!" without the necessary detailed information being furnished on present costs or on the factors that govern costs. In some places it is harder to learn the facts on costs than it is to discover the secret of the atom bomb.

Again, the design engineer who is expected to work miracles in cost reduction (and often does) frequently is nearer the low end of the salary scale than the high. It is asking a lot of human nature to expect such a man to extend himself in paring costs "for the company" without any sort of incentive such as certain other types of employees enjoy.

To achieve maximum effectiveness in reducing costs through design two conditions, at least, are essential:

1. Design engineers must have access to cost data, even of the "confidential" variety if necessary
2. Adequate incentive to cut costs must be offered to designers.

Through a program based on these principles the design engineer acquires an understanding of where the cost-cutting potentials are, as well as how cost savings may have a direct effect on the stability of his own job. Being in the confidence of management and in a position to participate financially in the benefits of his own efforts, through some sort of bonus, incentive or profit-sharing plan, the design engineer is faced with a new personal challenge. Reinforcing his natural pride in a job well done, this additional challenge can bring out latent ingenuity in designing particularly for economy and can spell the difference between mere interest and genuine enthusiasm.

Colin Carmichael

EDITOR

# DEVELOPING NEW PRODUCTS

ENGINEERING development perspective is provided dynamic emphasis in this statement of a business executive, "Eighty-five per cent of our business volume today comes from products we didn't know about ten years ago. At the same time, older members of our product family earn more today than they did ten years ago." Any business man would be proud of such a record of operating achievement.

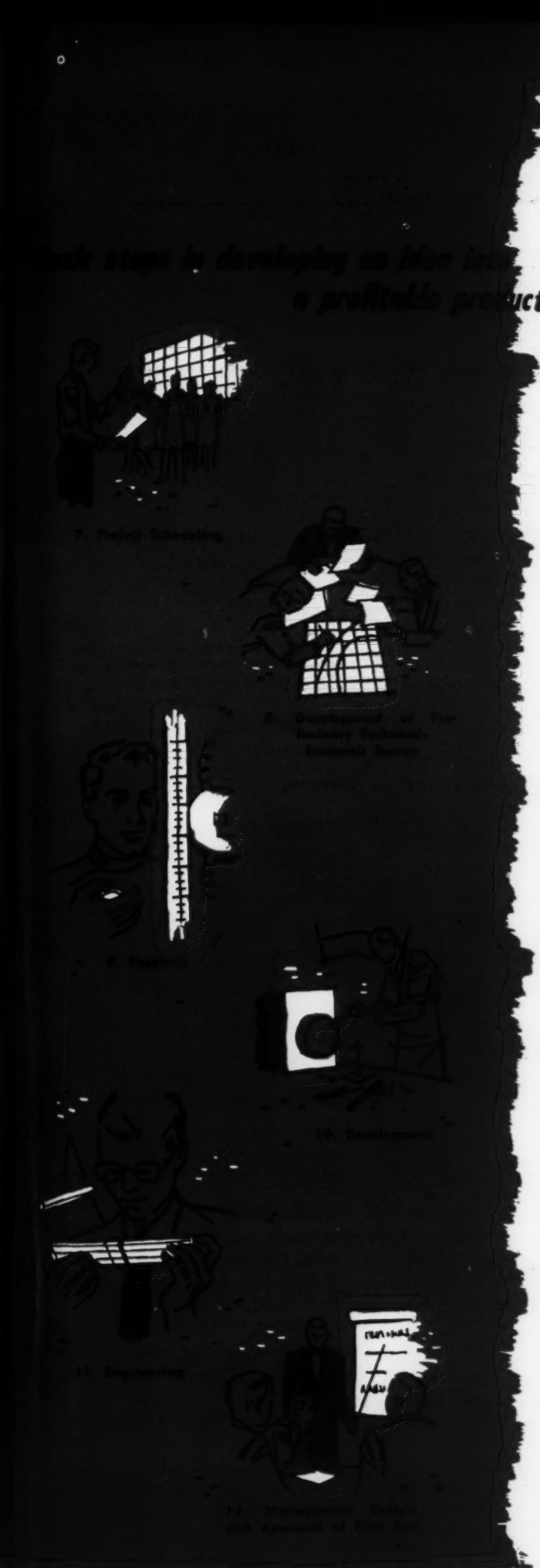
Product development represents one of the few remaining frontiers open to businessmen. Horizons are unlimited. Opportunities abound. Product programming is "big business" in big businesses because large, established corporations recognize this vital function.

New product development scares some executives. Too risky, they say. But it wasn't too risky for their grandfathers who founded the business. Risk is an inherent element in progress. All business involves risk. It can be a calculated risk. Successful development programs are built with calculated risks and executives can reduce the element of risk in their programs to a level where they are comparable to credit risks.

**Systematic Planning of Programs:** Development programming of this type can be executed by any firm that sets up its development program in the same way that it sets up its accounting system. Under such a system, a calculated risk is built into the program in the same manner in which it is built into an accounting system.

In accounting systems the degree of risk is dependent upon the thoroughness of checking data, accuracy of data, and by establishing criteria to act as controls. If John Doe wishes to borrow money, he must apply for credit in a manner dictated by the system of a particular bank, credit union, or other institution. Their respective systems dictate the procedure to be followed in collecting data about John Doe and this collected data is evaluated in accordance with established criteria. The directors of the institution determined the risk they would absorb in extending credit when they indicated the data that would be required concerning John Doe and the tests that this data would be required to meet.

Successful firms depend on product programs that function on such a systematic basis. All new product



# Basic steps in developing an idea into a profitable production item

By Philip R. Marvin
*Vice President*
*Commonwealth Engineering Co.*
*Dayton, Ohio*

ideas must be developed through each of the steps and meet the requirements of criteria established for the various steps along the course of development. Ideas that meet these tests become products in the corporation's product line.

In sharp contrast is the product development practice of the corporation that expects its new idea to grow like Topsy. Often failure shows up at a discouragingly late date after the investment of sizable sums of money. To point this up, one case is extremely pertinent in illustrating trouble caused by lack of planning. A medium sized manufacturer conceived a particularly novel electrical appliance and after some research and development modeled the device. He ran some spot field tests and the results were most favorable to the further development of the product. Production was scheduled and a national advertising program was undertaken. Everything proceeded according to schedule and deliveries were made to retailers. Then the program came to an abrupt halt. No major outlet could put the product on sale because the product did not carry the all important label that the Underwriters' Laboratories make available for manufacturer's products that have been submitted for fire insurance safety certification. Major outlets require such certification in order that they, as retailers, may qualify for product insurance on their merchandise.

Since these outlets would not stock the item, national advertising was not worthwhile and without this, production volume would be reduced to a point where the product would be priced right out of the market.

This firm barely survived the delay encountered by the new test period required, minor design change period to incorporate the added customer safety features in the device, final test period and reprocessing time to incorporate the new features in existing stock.

In systematic programs, Underwriters' Laboratories tests are always a major consideration during the development of the prototype model. While systems are not and cannot be claimed to be infallible, they are highly successful in reducing costly errors.

**Steps in Idea Development:** Ideas pass through thirty-three steps before they become successful end prod-

## Table 1—Steps From Idea To Production

### 1. Product Concept.

Basic product ideas are established and defined.

### 2. Preliminary Screening.

An initial appraisal to eliminate product ideas obviously impractical or otherwise unacceptable.

### 3. Patent Search.

Identify controlling patents, licenses and unprotected areas.

### 4. Preliminary Technical-Economic Survey.

General investigation to assess:
- Practicability of the product
- Nature and size of market
- Sales methods
- Manufacturing requirements
- Management, personnel and organization requirements
- Profit potential (effect of taxes)
- Breadth of corporate charter

### 5. Literature Search.

Available literature relating to the product concept and the market should be reviewed and pertinent data accumulated.

### 6. Final Screening.

Acceptance or rejection of ideas at this point is based upon findings of the literature search, preliminary technical-economic survey and the patent search.

### 7. Project Scheduling.

Assign:
- Funds—Establish a budget adequate for development and preliminary market testing
- Priority—Establish a timetable
- Manpower—Establish an organization

### 8. Development of Preliminary Technical-Economic Survey.

Amplify investigation of subjects covered in the preliminary technical-economic survey and establish basic acceptability of product for commercial exploitation.

### 9. Research.

Establish basic new principles and data related to the project.

### 10. Development.

Construct a preliminary model.

### 11. Engineering.

Incorporate sound principles of construction in the model.

### 12. Management Review and Approval of Pilot Run.

Based upon data available management should determine the advisability of a pilot run for the purpose of gathering additional manufacturing and marketing data.

### 13. Design Review.

Prior to a pilot run, the design should be reviewed to make certain that it incorporates the best features for:
- Performance.
- Production.
- Serviceability.
- Cost.
- Sales appeal.

### 14. Prototype Model.

A model is constructed which represents the product to be offered for sale.

### 15. Engineering Tests.

The prototype model is given a performance test in the engineering department.

### 16. Field Tests.

The prototype model is given a test under actual working conditions.

### 17. Review of Test Data.

Test data are analyzed and designs are revised to improve:
- Performance.
- Ease of manufacturing.
- Serviceability.
- Cost savings.
- Sales appeal.

### 18. Redesign.

The prototype model is redesigned to incorporate new design features. Final product styling is also incorporated in the model at this point.

### 19. Production Review and Redesign.

The design is reviewed and design modifications made to improve ease of production and to lower cost.

### 20. Final Model.

All final design modifications are incorporated in this model.

### 21. Preliminary Production Analysis.

The design is processed for manufacturing.

### 22. Elements to be Manufactured.

Parts of the product to be manufactured by the corporation are selected.

### 23. Elements to be Purchased.

Parts and sub-assemblies of the product to be purchased are selected.

### 24. Realistic Cost Analysis.

Manufacturing and purchased parts costs are established.

### 25. Pilot Run.

A small quantity of the product is produced to test manufacturing cost estimates and the marketing program.

### 26. Initial Market Test.

The pilot run is marketed in a selected area for experimental and analytical purposes.

### 27. Management Review and Approval of Production Release.

Results of the market test are examined by management. If the profit outlook appears favorable, production is released.

### 28. Service Organization.

Service facilities are organized.

### 29. Distribution Organization.

Distribution channels are organized.

### 30. Installation of General Sales Organization.

The selling organization is installed along with service facilities.

### 31. Production Tooling.

Equipment, tools, gages and fixtures are made ready for production.

### 32. Production.

Manufacture commences.

### 33. "Bread and Butter" Production and Distribution.

The product is manufactured and sold.

ucts. Steps assume varying degrees of importance, but each must be evaluated. An omission can be an open door to trouble.

These thirty-three important steps are completely outlined in the listing shown in TABLE 1 along with pertinent comments.

**Time to do the Job:** Action is the catalyst in any successful program. Product programs that are well planned are headed toward successful outcomes, but only if they are placed in motion. One corporation that has enjoyed prosperity for several generations of owners has a well qualified research and development committee. The members of this committee have been appointed with great care after a review of performance in their respective departments. To further attest to their skill as a research and development committee, fifteen product ideas they have selected as having great potential have all in the past ten years been successfully introduced on the market—by other firms.

Why?—because they don't have time to develop the products they locate. These men, these committee members, have more than full time jobs in their regular duties. They can squeeze some time out for committee meetings but these meetings tax reserves.

Mechanical product development takes time. Someone, somewhere must make this time available or product programs won't move. To execute a program, management and staff time must be scheduled for the job. The day of the indispensable man is over. A product program is important to the corporation. If there isn't personnel time available to do the job, management's first job is to locate personnel to do the job.

**Perspective in Programming:** Good engineering management incorporates perspective when its executives can see objectives, facilities, and the scope of the development problem and see these three in their proper relationship simultaneously. This is a real stumbling block in any program because the man who meets this test is usually too busy to make time available for the job.

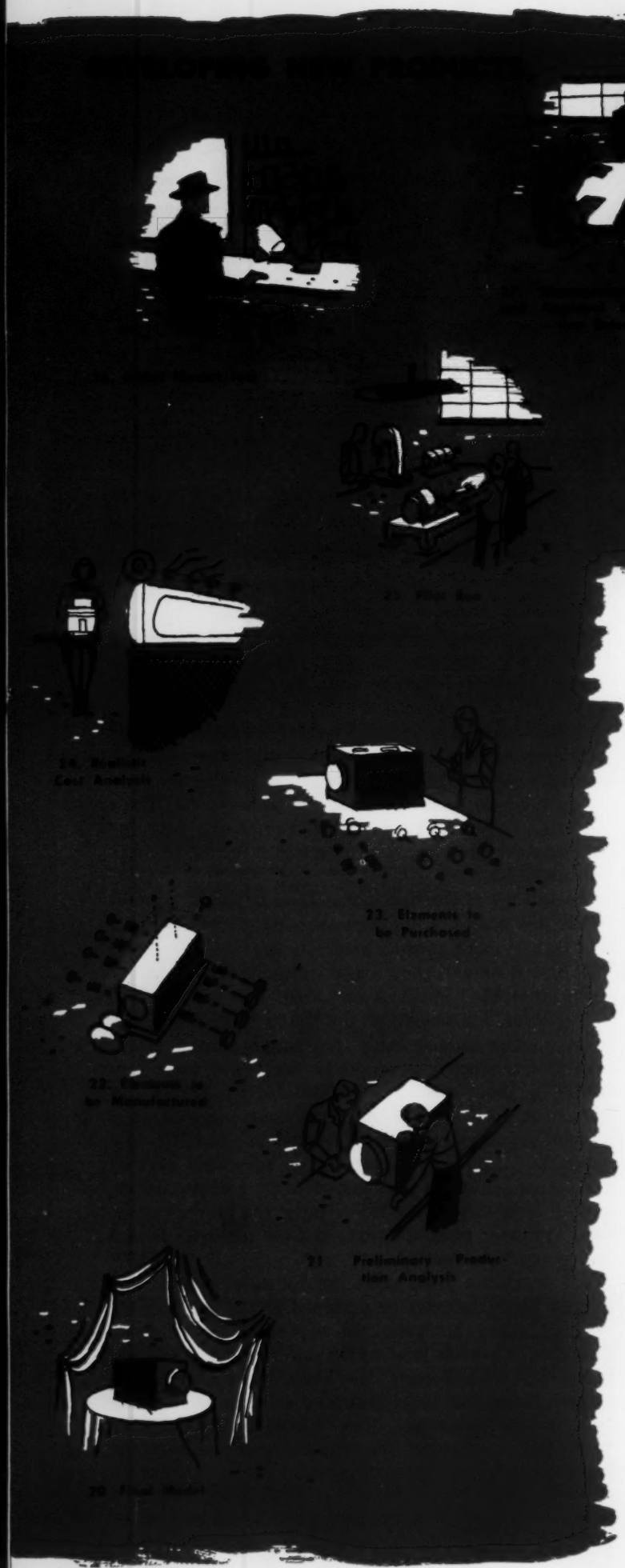
A successful machine tool builder is currently faced with this problem. His chief executive is overloaded. He can't devote time to product development. Yet product development has been the basis for the firm's growth. Unless someone injects perspective into the development program it will certainly fail to accomplish its objectives.

Knowledge of the firm's objectives is a vital ingredient in this mix. Such questions as (1) To what extent will management approve radically new ventures? and (2) How soon will they expect tangible results in the form of profits? must be answered.

Moreover, knowledge of the firm's facilities, equipment, and personnel enter into sound programming. Any new product program, to be successful, must capitalize on these assets. Utilization of equipment and personnel both from a short-run and long-run view should be taken into consideration in planning new products. All these factors are a very real part of the economics of the problem. Finally, perspective requires the ability to see the scope of the product problem. Product programs extend from ideas to "bread and butter" production.

All programs must start out by developing a flow of new ideas that can be screened in the final phases of preliminary analysis. In a product development program, a search is a major undertaking. The job is not just to get some new ideas, but rather to try to get all the new ideas that may exist anywhere that bear on the program. Since competitors are trying to do the same thing, the search becomes a race for ideas.

Executives closely concerned with going products admit that they are uncomfortable when dealing with new products. One executive remarked that he is aware that new products are essential but is forth-




right in admitting that he just can't carry through programs with any degree of enthusiasm.

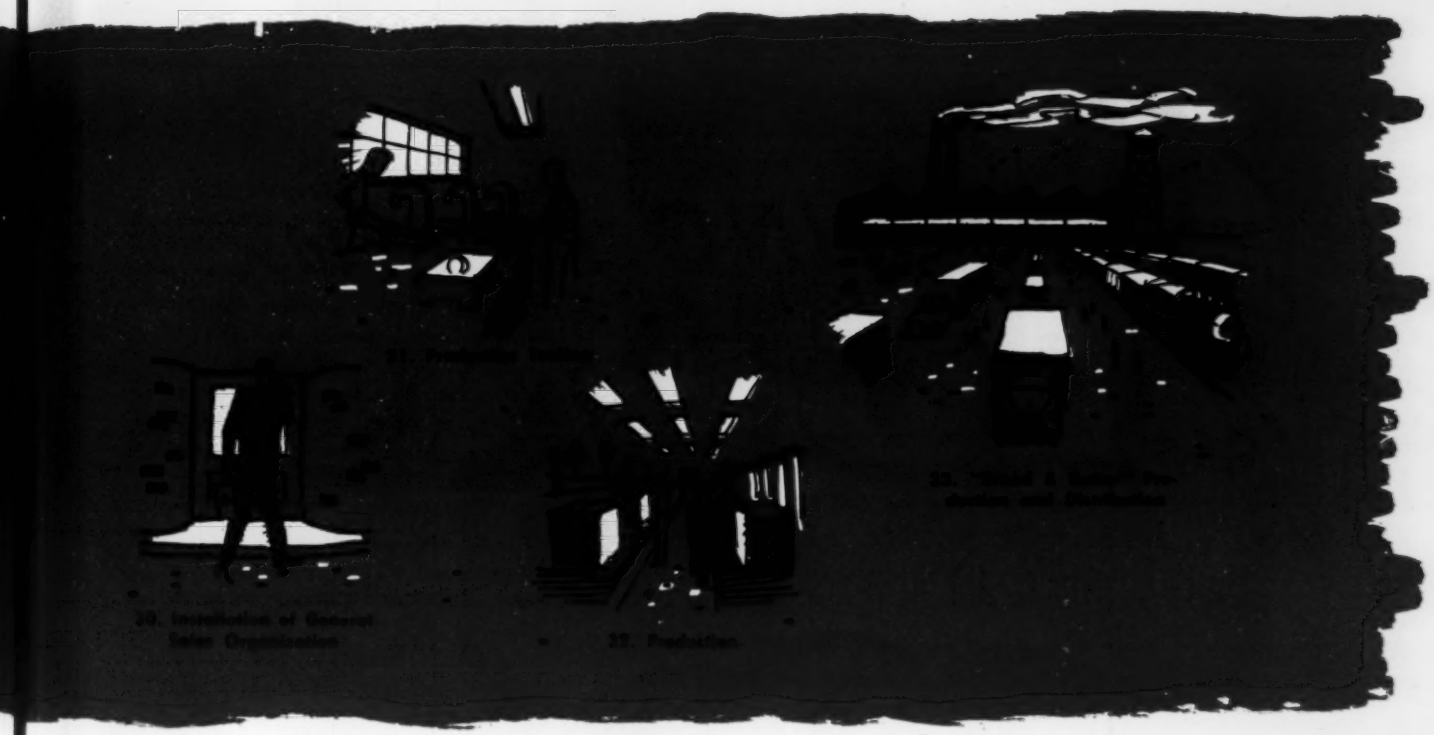
"New product ideas don't have any handles," he says. "I am used to thinking in terms which involve certainty, know-how, and experience. New product ideas represent departures from everything I have been schooled by training and practice to guide my thinking." On the other hand, the product development manager should be equally adept at dealing with these novel ideas. He should see "handles."

**Incorporating Know-How:** At a meeting called to consider the corporation's product line for the coming year, a number of carefully considered ideas were thrown on the table for consideration by the president, the sales manager, the production manager, and a member of the board of directors who followed such matters closely. The discussion lasted several hours and a decision was reached to go forward with several of the ideas.

This case is significant because it has been duplicated many times. To management men, it recalls other such similar situations in which they have been active participants. They can probably anticipate the course of events which followed.

Little progress was reported at the next meeting. Each of the men present at the meeting had taken some action but an overall view revealed that the action that had been taken was essentially ineffective. The decision to go forward meant different things to the different men. Urgency is a word inherently relative and subject to interpretation in varying degrees.

The primary difficulty that these men faced was the difficulty of finding the handles to use in taking hold of a new product idea. The steps in the development of an idea into a product are in themselves a tool. They focus attention on one phase of the process at a time.



Some are more adept at executing these steps than others. Principally this is a mattere of experience, a matter of combining background, skill, and knowledge gained through practice. These ingredients are the important ones in any phase of business operations.

Either such skill must be located within the organization or it must be brought into the organization from the outside by means of one of the several ways in which this can be accomplished. It must be made available. The most successful product programs are those that are managed by people who know how to do this job because they have done it before successfully.

**Toleration of Independence:** If a product is new, it is different. If it is different, it does not conform to all of the established concepts of finance, production, and distribution that are so familiar to the executive mind.

Expect the new product idea to unfold a series of new concepts. This contribution to executive thinking, and the stimulating challenge which accompanies, could well turn out to be of as much value, and maybe even more, to the corporation's operations than the value of the new product that catalysed these intangible returns.

Tolerance like virtue has its own rewards. This is especially true when dealing with the creative powers of the inventor's and researcher's mind.

**Necessary Tools:** Product programs should be expected to have requirements in the way of tools of the trade. These will depend on the nature of the program and the scope of its activities. They range from a workbench at one extreme, to a research laboratory at the other, and include libraries, specialists and pilot facilities. Stand-by capacity in both early and late phases of development is also a valuable tool.

Development devoid of these will degenerate. Judgment, judicious in its selection and utilization of these scarce and costly tools, contributes as much to the ultimate success of development as the product of the creative mind. Either too much too soon or too little too late can cost valuable time and money.

**Planning for Profits:** Product programming calls for a realistic approach. The future is the stake. Recognize all the steps between ideas and production, find time to do the job, provide for perspective in programming, incorporate knowhow, tolerate independence and make tools available. Basic problems must be pinpointed. The importance, place, and cost of compromises must be recognized.

This is management planning for profits.

---

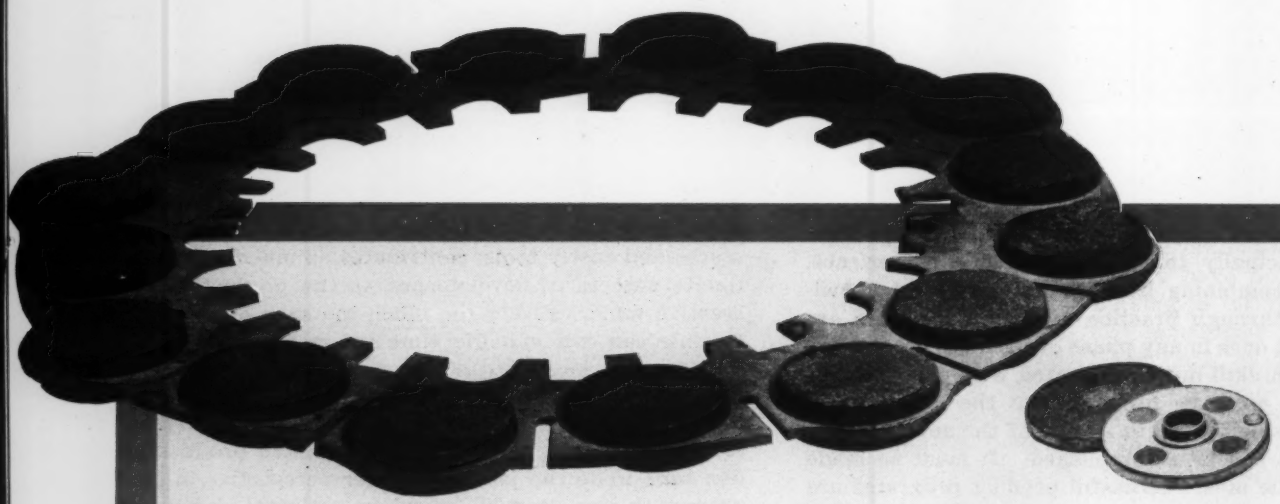
## *They Say . . .*

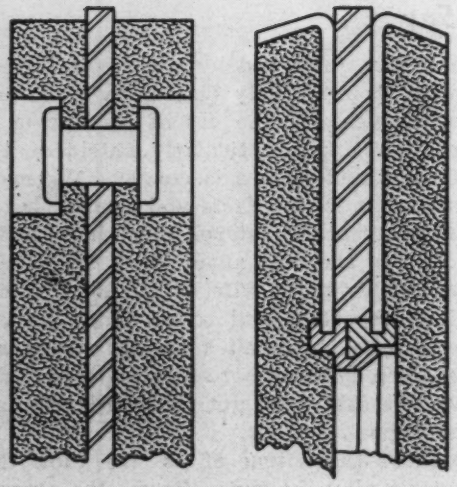
"It has been remarked by some who have viewed our profession objectively that many of us are short in persuasiveness, in the art of convincing or persuading others, and particularly outsiders, that our view of facts and figures is correct. We may know the truth—that is, the facts and figures, but we are not always adept at interpreting them for others. You recall the anecdote about Mark Twain, a swearing man, and his gentle wife. When Mark's collar button fell on the floor and rolled away his language was pretty bad. He didn't know his wife was within hearing. Then he heard her repeating his exact words.

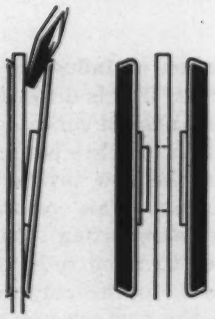
" 'Livy,' he said, 'you got the words all right, but you don't know the music.'

"Sometimes that's true of us. We know the facts but we can't play the tune. Maybe the answer is to be found in making up our minds to learn the music and then to practice it."—LEWIS A. VINCENT, *general manager, National Board of Fire Underwriters.*

# SCANNING the field for IDEAS

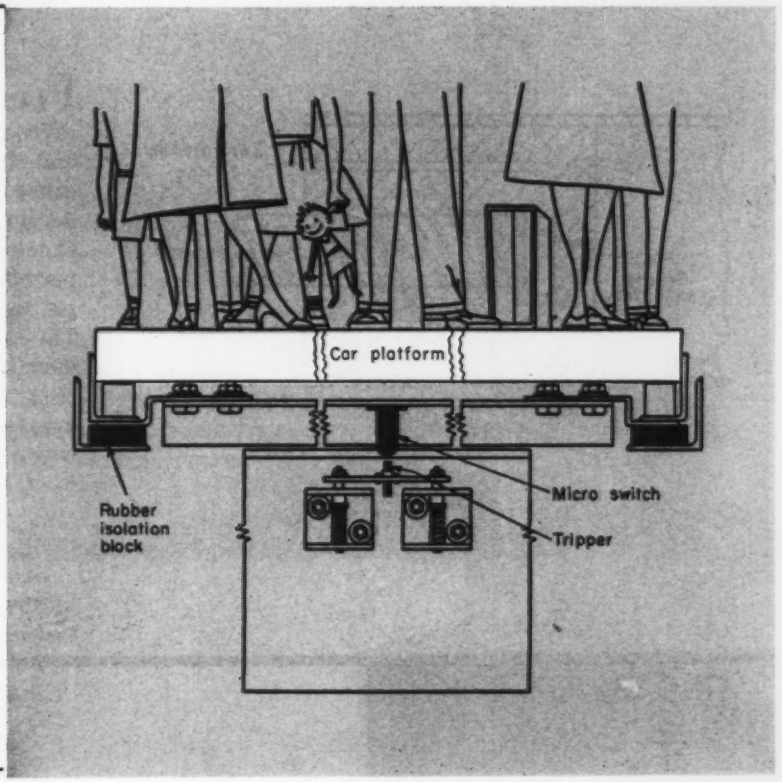




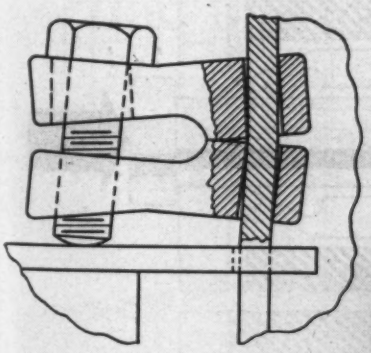


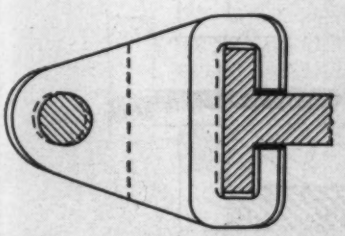
**PRESSED-IN FRICTION SURFACES** for multiple disc brakes eliminate conventional rivets or bonding and reduce wear and maintenance problems. Cermetallic brake lining developed by Bendix Products Div. of Bendix Aviation Corp. employs a ceramic-base friction material retained in shallow metal cups which are snap-fastened to the brake stators. Design of the discs eliminates run-in, improves braking surface ventilation, facilitates heat conductivity and resists deterioration from wear and temperature. In addition relining time is substantially reduced and the elimination of rivets increases the usable lining thickness available for wear.

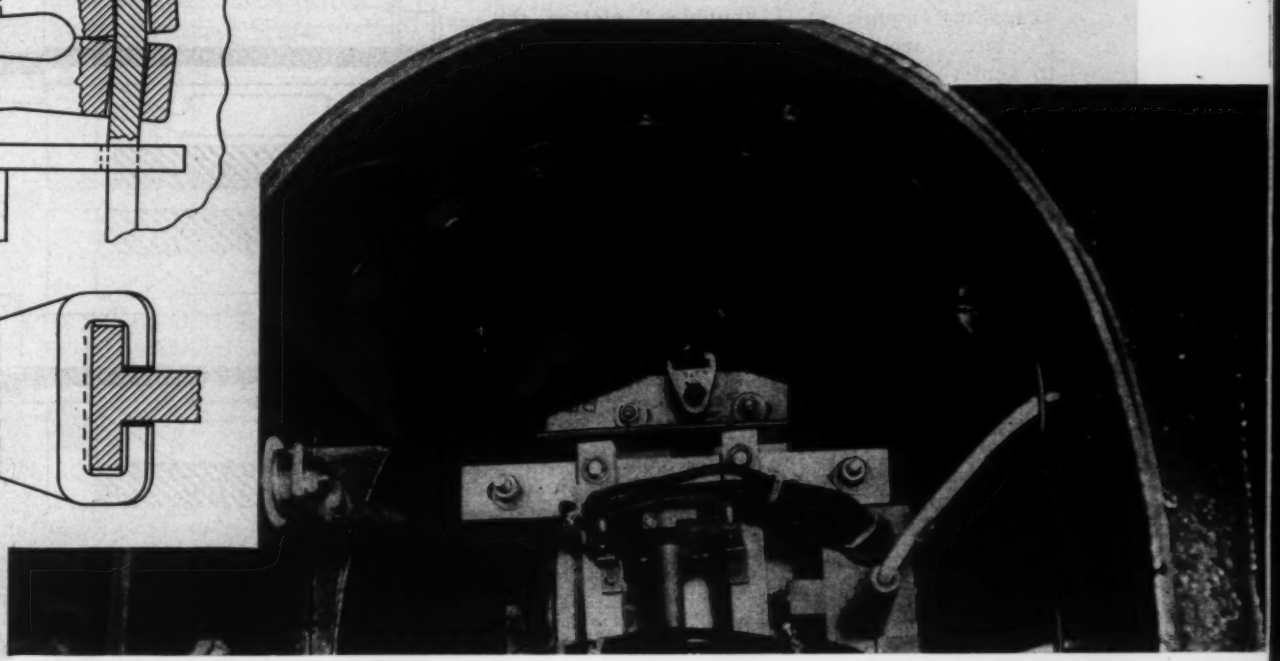
**AUTOMATIC LOAD MONITORING** to expedite traffic in Otis elevator systems operating without attendants is achieved with a novel deflection weighing mechanism. Compression of rubber-pads under the car platform by interior passenger loads trips a Microswitch, dispatching the car from a terminal ahead of time and causing the filled car to run "express." Operation of the device permits the car to answer interior signals but outside calls are bypassed until the load is reduced sufficiently to take on more passengers. Design of the tripper permits adjustment for desired load capacity.

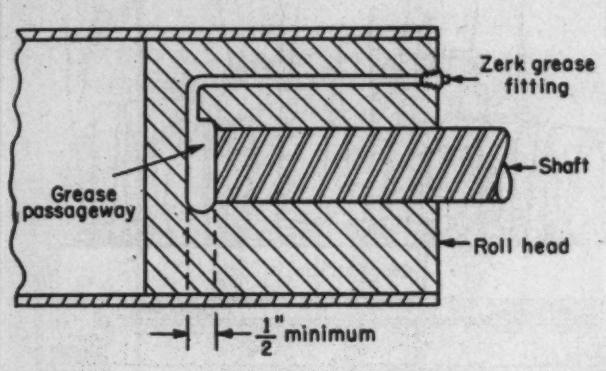



**ACCURATE LOCKING** for position and retention of heavy or bulky equipment is obtained with a novel clamp design developed by Frank Surenda of the Pittsburgh Works of Allis-Chalmers Mfg. Co. Employed with T-shaped guide rails, the clamp consists of two bolt-connected elements which abut against the mounted equipment and are designed to slide along the rails for position adjustments. Tightening of the bolt creates a jamming action, securely locking the clamp and the bolt adjustment.

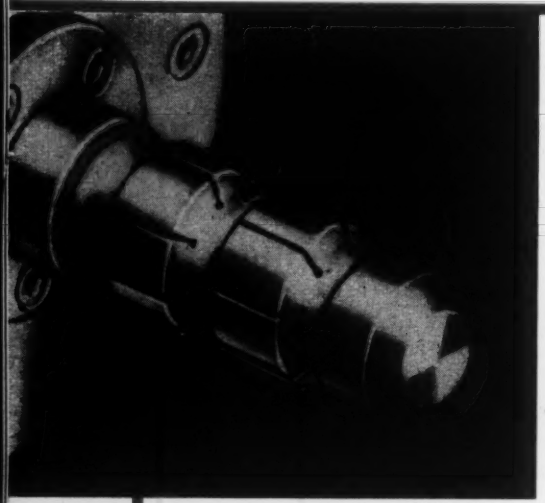




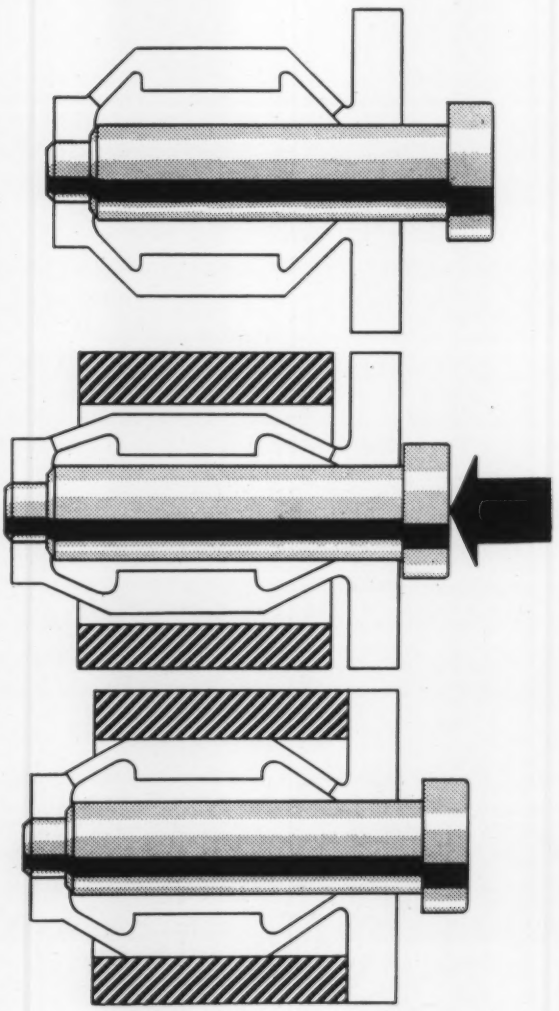


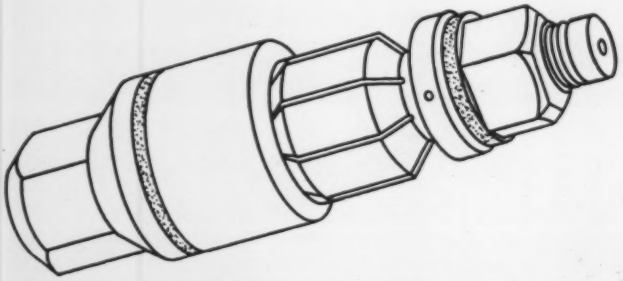



**FLUID PRESSURE EJECTION** of shafts in press-fitted assemblies facilitates maintenance and simplifies troublesome disassembly problems caused by breakage. In the "Renu-Shaft" rolls developed by Rodney Hunt Machine Co., a passageway in the roll head, closed by a Zerk fitting, permits grease under pressures up to 10,000 psi to be fed to the end of a press-fitted shaft. The large end force generated causes steady removal of the shaft, reducing disassembly time to a few minutes. To assemble the shaft, the grease passage is filled, the shaft is driven to within ½-inch full depth and the Zerk fitting is closed.



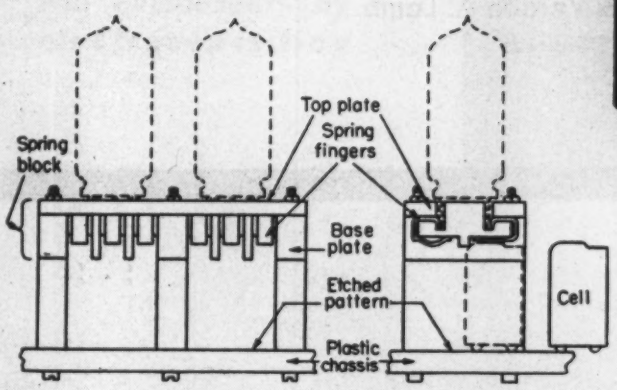
**EXPANSION LOCKING** of rotating members without setscrews or keyways provides a secure connection for torque transmission and eliminates surface discontinuities. Developed by N. A. Woodworth Co., expanding hollow steel "bubbles," slotted for flexibility, are employed on a diaphragm arbor to achieve rapid, precision internal chucking of parts. Forced elongation of the bubble reduces the outside diameter and permits assembly of parts. Expansion of the bubble when the force is removed locks the parts securely in place. Accurate, concentric alignment of parts is assured by the design which may be manual or power operated.

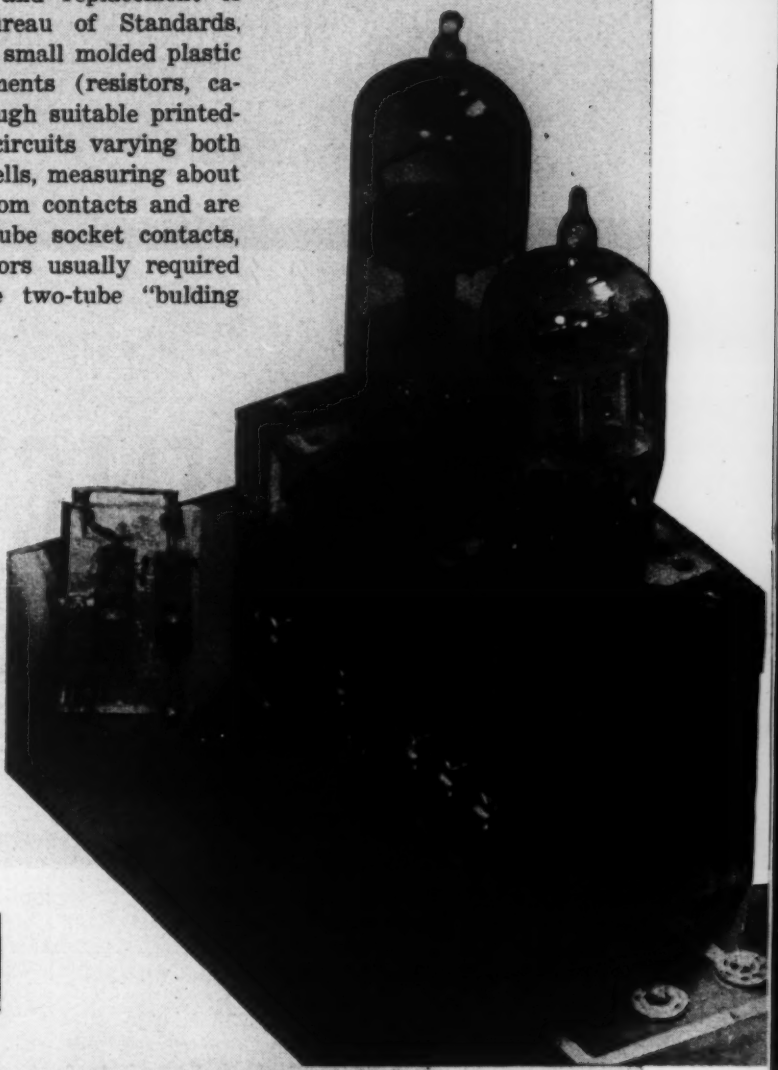


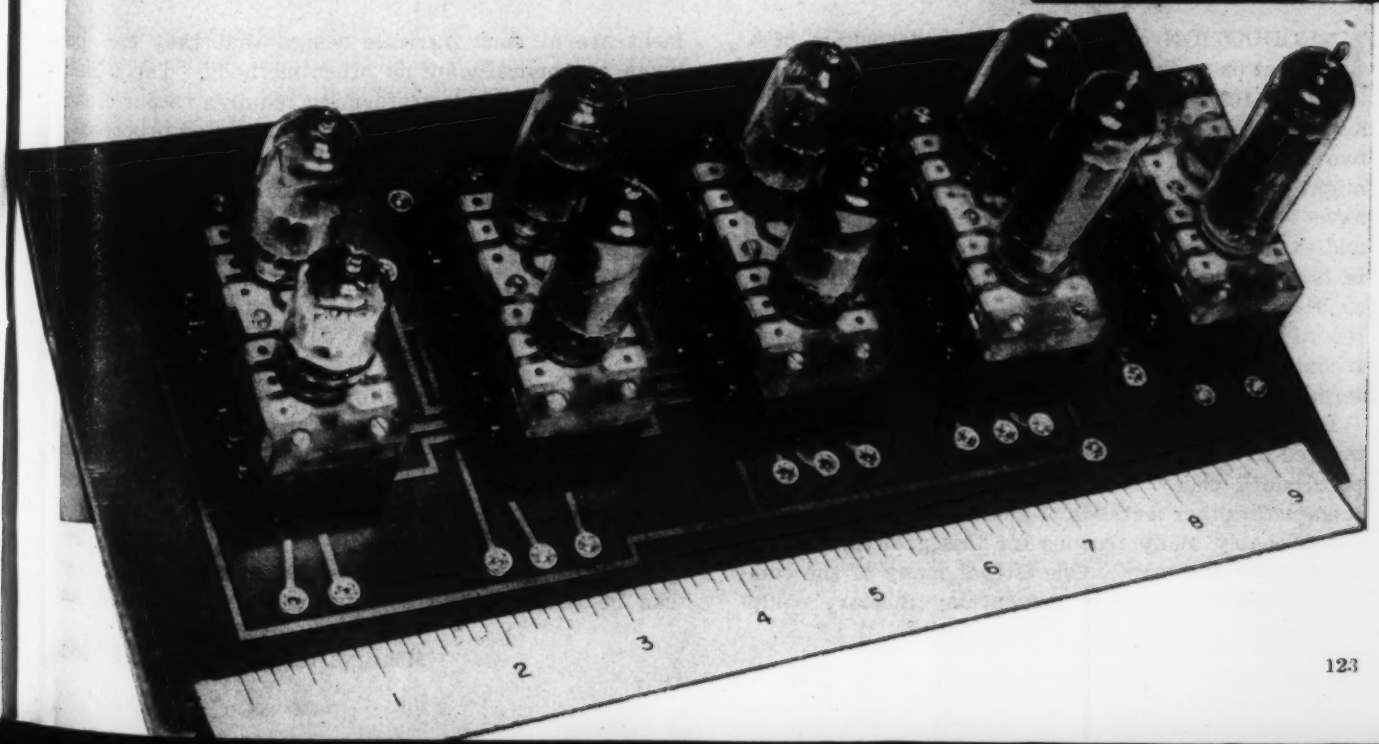


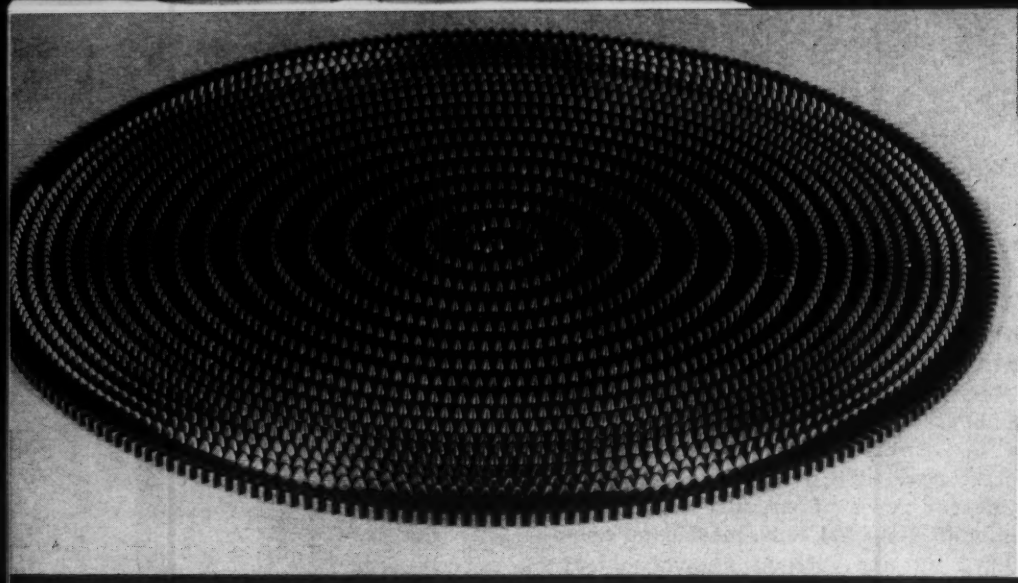
# IDEAS

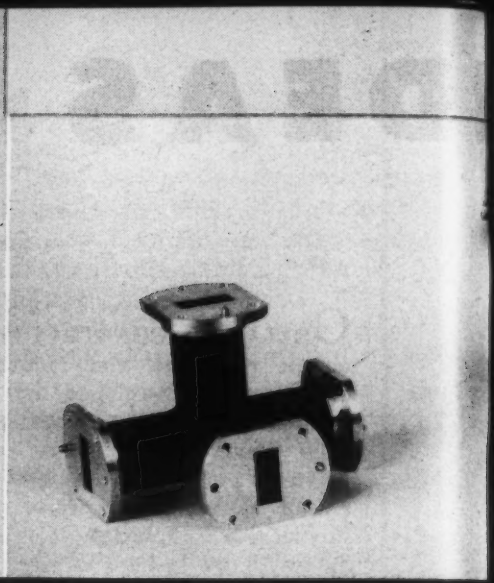
**CELLULAR CONSTRUCTION** of electronic assemblies improves circuit reliability and facilitates maintenance and replacement of components. Developed by the National Bureau of Standards, standardized two-tube subassemblies built-up of small molded plastic cells, each containing one or two circuit elements (resistors, capacitors, inductors), can be interconnected through suitable printed-circuit base plates to form different types of circuits varying both in size and complexity. The individual molded cells, measuring about ⅞ by ½ by ¼-inch in size, have top and bottom contacts and are held in place by spring extensions from the tube socket contacts, eliminating the soldering and multiple connectors usually required and facilitating replacement. In addition, the two-tube "bulding blocks," which are secured to the base plate by screws, can readily be removed as a unit for rapid repair and maintenance. Modifications in cell size, number of tubes and printed-circuit patterns offer further possibilities for increased flexibility in meeting equipment requirements.









# DESIGNING ELECTROFORMED PAR

By William H. Metzger Jr. & Vernon A. Lamb

*National Bureau of Standards*
*Washington, D. C.*

PRODUCTION of parts by electrodeposition of a metal on a removable mold or matrix is a process over 100 years old. It was first applied to the manufacture of electrotypes by a Russian, Jacobi, and two Englishmen, Spencer and Jordan, in 1839. It might be expected that a process known so long would have been developed to a high degree of perfection and extensive applications many years ago. The fact is, however, that except for a few special applications, such as production of electrotypes and phonograph record dies, the uses of electroforming prior to fairly recent years were few and far between, and many enterprises in this field were short-lived.

In the past 10 to 15 years, electroforming has been applied to a wide variety of articles at an accelerating pace, until today it occupies a significant position along with other methods of metal fabrication. There are probably many reasons for this growth, but two seem to be dominant. One is that many of the component parts needed in present-day military equipment are of such intricate design that they can be made economically by no other methods. The other is that successful electroforming requires rather close technical control of the plating and related processes, and it is only during relatively recent years that plating has evolved from an art to an accurately controlled process.

This expansion in the applications and volume of electroforming justify considering some aspects of the subject that have direct applications for the design engineer.

**Application of Electroforming:** Design engineers can be guided by certain general principles in deciding whether electroforming is a feasible method for making a given part. Following are some of the more important criteria:

FORM: Many shapes can be electroformed, both simple and complex. If parts are of such form that they can be readily made by standard methods, such as

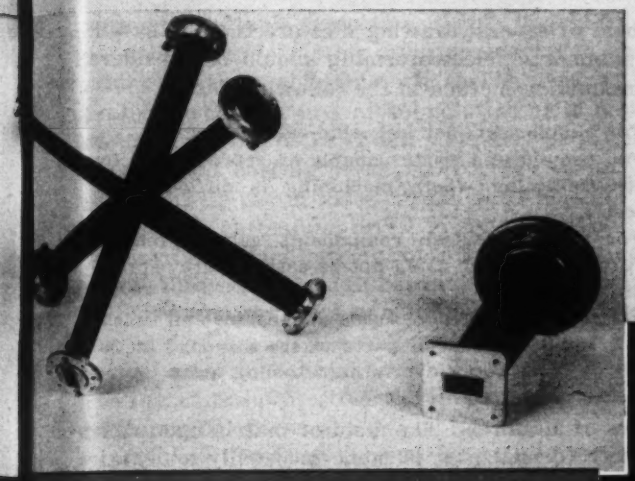
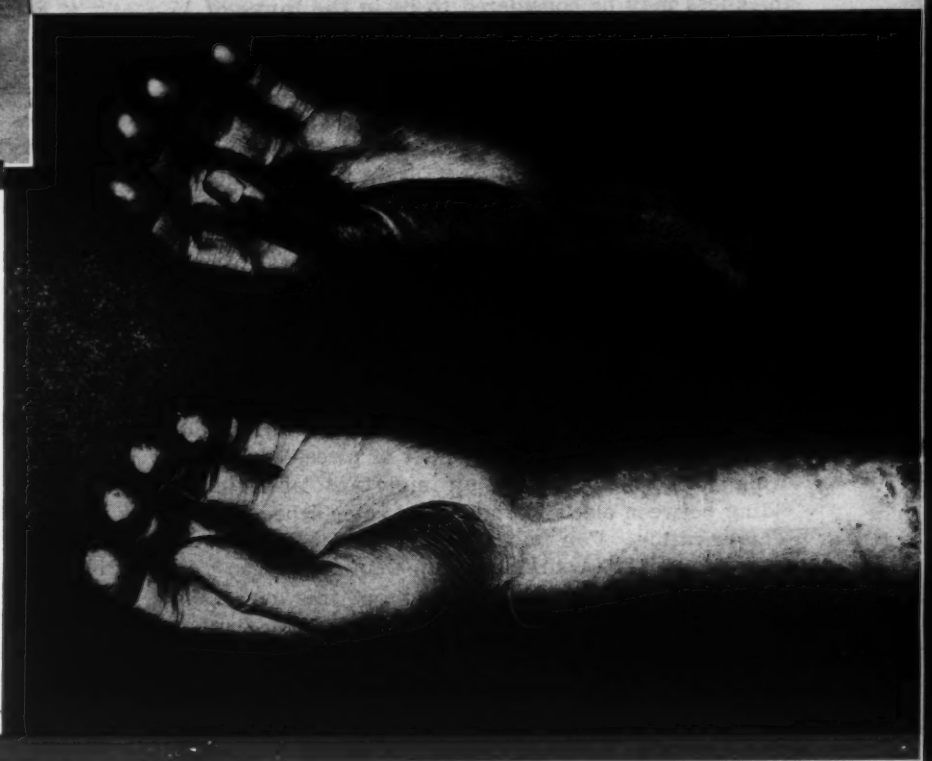


Fig. 1—Extreme Left—Spiral pin cam used in computing mechanisms. Courtesy U. S. Rubber Co.

Fig. 2—Left—Waveguide components, including magic T, six-arm bridge, and transition section

Fig. 3—Below—Flexible plastic glove, top, formed in electroformed hand mold, bottom. Courtesy Army Prosthetics Laboratory



RTS

***Considerations for obtaining most satisfactory and economical components by electrodeposition***

machining, casting, stamping or drawing, electroforming cannot usually compete on a cost basis. However, even in the case of simple shapes, electroforming is sometimes the best fabrication method. For example, a thin-walled part such as a pen-cap has been successfully and economically manufactured by electroforming. The thin wall permits a high rate of production and makes possible a good as-plated finish. An additional advantage in this application is that a machining operation that is required for mechanically formed caps is unnecessary with the electroformed caps.

On the other hand, electroforming is not restricted to simple shapes. On the contrary, one of its important advantages is that shapes that are too complicated to produce economically by standard methods can be reproduced at a practical cost by electroforming. A good example is a spiral pin-cam used in computing mechanisms, *Fig.* 1.

Another example of a complicated shape is the six arm bridge shown in *Fig.* 2. In this case the matrix is assembled from six closely-fitting arms held together with screws. On completion of electroforming, the screws are removed and each arm of the matrix is individually withdrawn from the electroform. A built-up matrix of this type can often be used when the shape would not permit the withdrawal of a one-piece matrix.

Another class of components that may be considered under the heading of form is that containing "grown-in" components. For example, pins or plates that are to project into the inside of a wave-guide can be incorporated in the mandrel. The electroformed metal adheres to or firmly embeds the projecting portion of the insert and it becomes an integral part of the completed piece. Likewise, contact wires can be "grown-in" to an electroformed commutator or slip-ring element.

SIZE: Parts of almost any size can be made by electroforming. The sizes of parts that have been

made range from tiny silver slip-ring assemblies to searchlight reflectors five feet in diameter. Even larger parts have been electroformed.

DEPOSIT THICKNESS: Parts such as hollow spheres and tubes have been made with wall thicknesses of only a few ten-thousandths of an inch. These parts could have been made by no other method. Thick deposits can also be readily made. Molds for plastics, and metal forming dies are examples of thick-walled electroformed parts. The practical upper limit of thickness may be considered to be in the range of ¼ to ½-inch. Cost naturally increases with deposit thickness.

ACCURACY OF REPRODUCTION: One of the important features of electroformed parts is the high accuracy of dimensions and finish that can be obtained. Scratches of the order of one-millionth of an inch in width or depth are accurately reproduced. Ability to reproduce a high surface finish is of special value in producing parts such as mold cavities for plastics, and waveguides for microwave transmission. The desired finish and tolerances can be readily applied to the outside surface of the matrix, and are automatically reproduced on the inside of the waveguide, whereas to achieve the same finish and accuracy on the inside by machining methods would be nearly impossible.

PRODUCTION RUNS: The number of pieces of a given design to be made may be an important factor in deciding between electroforming and some other method of fabrication. For example, suppose that an experimental assembly contains a cup-shaped part and, to determine the optimum dimensions of this part, trial of several sizes and shapes is necessary. The experimental parts can be readily made at moderate cost by electroforming. However, once the design is fixed, a large number of this design could be made at a lower cost by drawing. Much time and the relatively high cost of several drawing dies are thereby saved.

To summarize, electroforming should be considered as a production method in the following cases:

1. For simple, symmetrical, thin-walled parts.
2. For complicated parts capable of reproduction by electroforming where machining is difficult and costly.
3. For parts in which components can be readily "grown-in" which could not be assembled by standard methods.
4. For parts with critical inside dimensions and finish.
5. For small numbers of parts where standard methods of fabrication involve high tooling costs.

**Types of Mandrels:** The mold or matrix upon which the electroformed part is made is usually a negative of the desired product. An underdimensioned positive mold can also be used, but the outside surface of the product will not be an accurate reproduction of the part being made unless it is thin-walled.

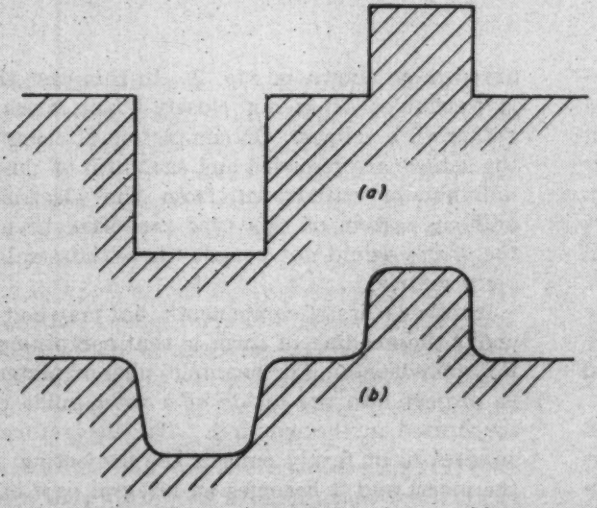
Matrices can be made by any standard method of fabrication, such as casting or machining. Electroforming is also a good method for making matrices. A number of highly accurate negative matrices may be made from a single machined positive.

Matrices may be classed as permanent, soluble, or fusible, and their basic characteristics are:

PERMANENT TYPES: A permanent, or reusable, matrix is used when shape is such that it can be withdrawn without damage to itself or to the electroformed part. A metal is usually used for this type of matrix although wood, glass, or plastic can be used. A wide choice of metals is available. Each matrix material has certain advantages and limitations. The more common materials are outlined.

*Plain Steel:* Plain steel can be machined accurately, is readily available, and cost is low. It cannot be used

Fig. 4—Below—Cross-sections of hypothetical matrix contours. Sharp corners, *a*, undesirable design, and, *b*, desirable design



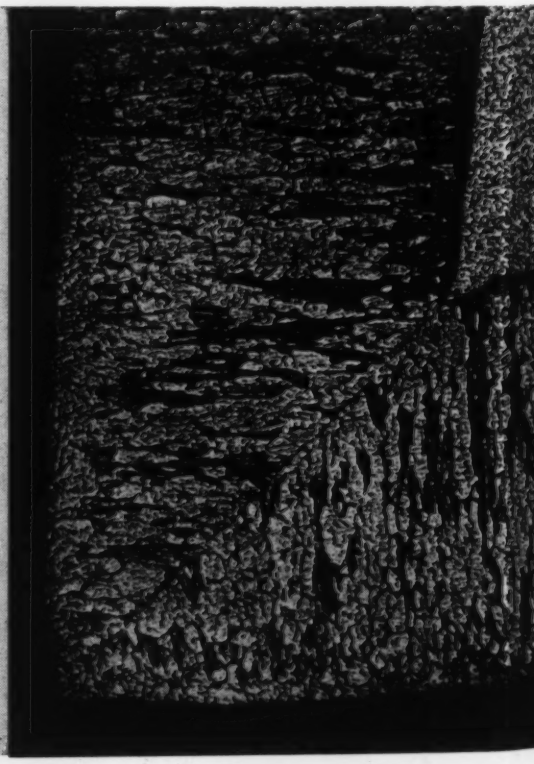



Fig. 5—Right—Photomicrograph of an acid copper deposit in a sharp right angle, showing in cross-section the weak cleavage plane formed by the juncture of the columnar crystals growing from each side of the angle. Magnification 50×

without a suitable protective coating in acid copper or hot iron-chloride plating solutions owing to chemical attack by these solutions. It can be used without a protective coating in a nickel solution or in any cyanide type plating bath. Plain steel may be plated with an adherent coating of any corrosion-resistant metal to permit its use in these corrosive baths. For example, nickel, chromium, or silver may be used. These coatings also facilitate formation of separating films on the matrix. The high hardness of a matrix coating of chromium prevents damage by accidental scratching or denting. If the matrix is to be used in a corrosive bath such as copper sulfate, a rather heavy coating of the protective metal should be used, e.g., a minimum thickness of 0.002-inch.

*Stainless Steel and Inconel:* These alloys have good corrosion resistance and are inert to most plating solutions. The natural oxide film, which is responsible for the passivity of these alloys, prevents adhesion of most deposits. However, it is usually desirable to insure passivity by special treatment. These alloys are not very hard and unless matrices made from them are very carefully handled, a high surface finish will be damaged.

*Invar and Kovar:* The important characteristic of these alloys is their unusually low coefficient of expansion. They also have natural passivity similar to that of stainless steel. High cost and poor machinability are disadvantages. They are most useful for long untapered matrices. In this situation, as a result of their low coefficient of expansion, heating of the electroformed part on the matrix may result in sufficient differential expansion to facilitate withdrawal.

*Brass:* Brass has good machinability and is low in cost compared with the special alloys. If it is plated with a suitable coating such as nickel, chromium, or silver, it can be used in any plating solution.

*Glass and Quartz:* These materials can be ground to extremely small tolerances and to a very high surface finish. High cost of machining and fragility are disadvantages. Surface strains may cause failure by crazing. Glass matrices must be coated with a conducting film. Silver, applied by either chemical reduction or by evaporation, is usually used.

*Wood, Plaster, Plastics*: High tolerances cannot be held with these materials, especially wood and plaster. Plaster matrices are likely to be damaged when removed and are therefore not strictly reusable, but are considered here because they are neither soluble nor fusible. The surface pores of both wood and plaster must be sealed with varnish or wax, and require application of an electrically conducting coating. Copper or silver powder in a lacquer vehicle is usually used. Plastic matrices can be made with a high finish and fairly small tolerances ($\pm$0.001-inch), which would be lost if a conducting lacquer were used to make the surface conductive. Therefore, a thin silver film is usually applied, either by chemical reduction or by evaporation.

These matrix materials have a definite place in some applications. For example, plaster is used to make

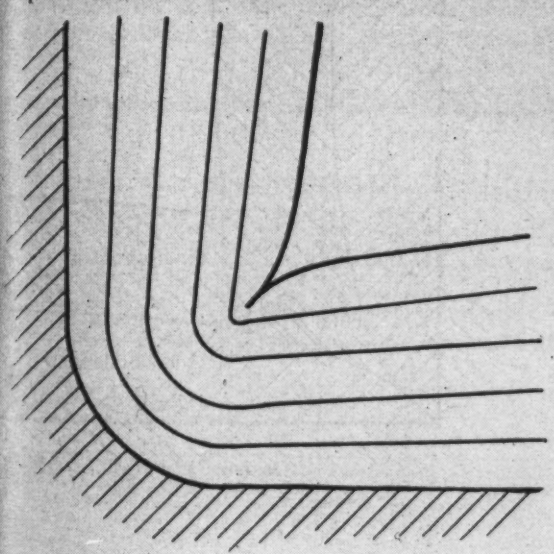


Fig. 6—Cross-section of an electrodeposit in a filleted internal right-angle. The lines indicate the changing form of the deposit in the corner with increase in thickness, and show the initiation of a cleavage plane in the corner when the deposit thickness exceeds the radius of the fillet

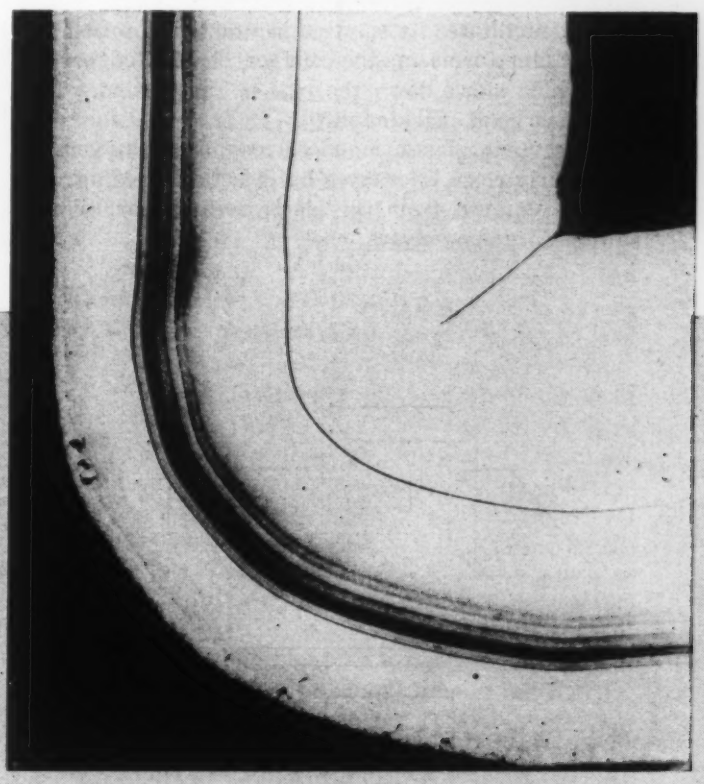


Fig. 7 — Photomicrograph of a PR cyanide copper deposit in a filleted internal right angle. This gives confirmation of the structure shown geometrically in *Fig.* 6. Deposit thickness: approximately 0.06-inch; radius: 0.04-inch; magnification, 50×

molds for art objects, face masks, etc. Flexible plastic or rubber molds are useful for large-tolerance parts with undercuts, because they can be withdrawn and reused. An interesting and important application of electroforming that utilizes a flexible matrix is the production of nickel molds for prosthetic gloves, used for covering mechanical hands for amputees, *Fig.* 3.

A special type of plastic matrix is one which remains a part of the finished article. Two examples of articles in this category are electroformed slip-rings and commutators, and electroformed circuits. Slip-rings and commutators are made by building up thick deposits of silver in grooves molded or machined into the plastic base. Electroformed circuits may be made by depositing silver or copper on a pattern printed with a conducting paint, in order to increase the conductivity of the circuit.

SOLUBLE TYPES: A soluble matrix is useful in the following situations: (1) When a higher finish and smaller tolerances are desired than can be obtained with a fusible matrix, but where a permanent matrix cannot be withdrawn; (2) in cases where creep would distort fusible metal or wax matrices; and (3) in cases where a thin-walled electroformed part has insufficient strength to permit withdrawal of the matrix.

Soluble matrices are most commonly made of aluminum, which can be dissolved by a caustic solution without attack of electroformed copper, silver, nickel or iron. Type 61S has been found to be a good aluminum alloy for this purpose, since its low copper content facilitates its solution in caustic—a protective copper film forms on the surface of high-copper alloys which slows down the rate of dissolution. This alloy has good machinability.

Polystyrene plastic matrices may be cheaply made with fairly close tolerances by injection molding, and can be removed from the electroformed part with a suitable organic solvent.

Steel or zinc matrices can be removed by dissolving in hydrochloric acid. Steel, however, is not very practical as a soluble matrix because it dissolves very slowly.

FUSIBLE TYPES: In cases where the shape will not permit withdrawal of the matrix but where the accuracy of a soluble matrix is not needed, fusible matrices are used. Made from either low-melting alloys or waxes, matrices are formed by casting, although wax matrices may also be pressure-molded. Casting may be done in simple molds of steel, plaster or wood, or in high-production applications by die-casting. Hollow spherical floats are generally produced with a cast positive matrix and, as a typical example, electrotype molds are made with molded matrices.

Alloys of the lead-tin-bismuth type, commonly with melting points of approximately 158 F, 255 F, and 281 F are commonly used low-melting alloys. Many waxes can be used as matrix materials, including paraffin, bee's wax, and electrotyper's wax. Tolerances as low as $\pm$0.002-inch may be obtained with cast metals and waxes.

SEPARATING AND CONDUCTING FILMS: Two subjects concerning matrices that are of much importance in electroforming are methods for separating the finished part from the matrix, and methods for applying conducting films to nonmetallic matrices. Several methods have been briefly indicated. These subjects are not of primary interest to the designer generally with the exception of one separation method.

It is sometimes advantageous to obtain separation of the electroform from the permanent metal type of matrix by plating the matrix with a thin deposit of a low-melting metal such as lead, tin, or cadmium, and then effect removal by melting the separating film. This method is especially useful in the case of deep cavities, or long tubes with no taper. If the dimen-

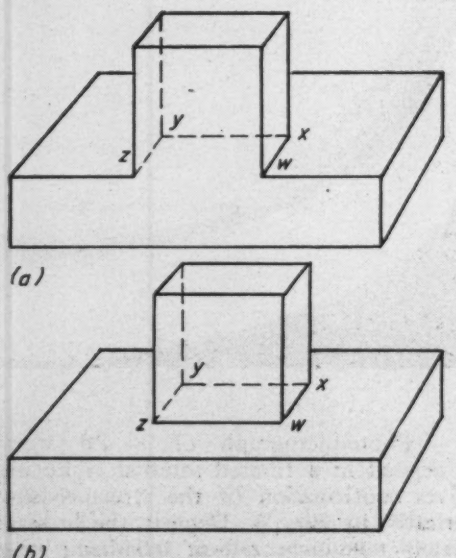
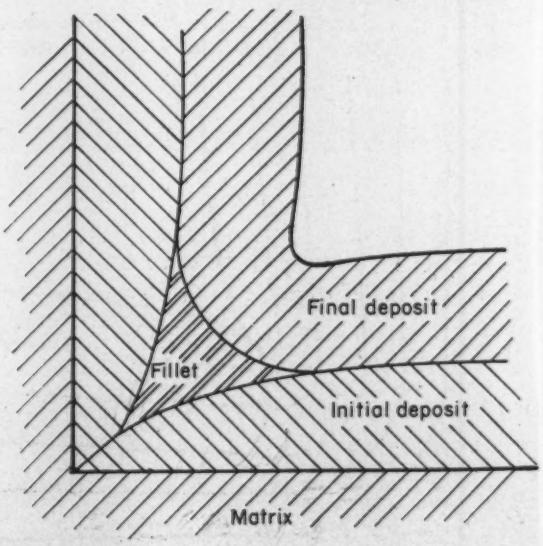



Fig. 8 — Left — Two types of matrix joints

Fig. 9—Right—Drawing of a cross-section of a deposit in a sharp internal right angle, showing a method for obtaining strength in the angle. The fillet is formed with solder, low-melting alloy, sprayed metal, or plastic. Cleavage plane is absent in the final deposit



sional tolerances are small, the matrix must be made undersize to compensate for the thickness of the fusible plate which is usually of the order of 0.001-inch.

**Design Factors:** Some design limitations have been indicated in the description of the types of components that can be electroformed. Most of these limitations are the result of the inability of a plating bath to produce a deposit of uniform thickness on an irregularly shaped matrix. A deposit tends to be thicker on projecting areas and thinner in recesses than the average thickness. If a recess is sufficiently deep, the bottom of the recess may receive no deposit at all. The degree of thickness uniformity which a given type of bath will produce on an irregular surface is a function of a qualitatively defined property of the bath, known as throwing power.

Acid-type plating solutions, such as iron, nickel, and copper sulfate, have relatively poor throwing power, while cyanide baths such as silver and copper have relatively good throwing power. The electroformer can compensate to some degree for irregularities in form and low throwing power by the use of auxiliary conforming anodes, "thieves" (cathodic elements that rob current from areas such as edges and projections), and shields (nonconducting plates arranged to deflect the current from projections).

These expedients add to the cost of the electroformed part and if the need for them can be eliminated by designing for electroforming, a gain has been made. Functional requirements may dictate shapes and designs which pose problems for the electroformer, but these problems will be lessened if the designer knows of the limited throwing power of plating solutions and if his goal is to minimize the problems arising therefrom. Observation of the following rules will aid in achieving this goal.

1. Recesses should be as wide and shallow as possible.
2. Sharp internal angles should be avoided wherever possible. Internal angles should preferably be obtuse, with fillets at their apices.
3. Projections preferably should have rounded contours and outside angles should have radii at their apices.

These rules are illustrated diagramatically in *Fig.* 4.

Quantitative data that would permit prediction of the deposit thickness on any part of a complicated shape would be very useful in electroforming. Unfortunately, such data do not exist, but certain qualitative relations between deposit thickness and angles can be predicted. For example, in internal angles, the thickness of the deposit in the apex relative to the thickness at a distance from the apex should be less the smaller the angle and the smaller the fillet radius. On the outside of an angle, the reverse of these relationships should apply.

The data in TABLE 1 illustrate these points and show the order of magnitude of the thickness variations that may be obtained. It will be noted in the table that the thickness ratios for 90 degrees, at the larger fillet radii, are out of line with the general rule. This is because the deposits on which these data are based were not all of the same thickness. The reason for a change in the thickness ratio with change in deposit thickness can be readily understood. For example, for an internal angle, the relatively thicker deposit at a point some distance from the apex causes the angle to become smaller with increase in thickness, and as the angle becomes smaller, relatively less metal is deposited in the apex. The data in TABLE 1 can, therefore, be used only as a rough guide for estimating deposit distribution in angles. The throwing power of nickel and iron baths is similar to that of the acid copper sulfate bath.

Distribution of copper or silver plated in or on angles from cyanide baths will be more uniform than that shown in TABLE 1, because, as stated above, cyanide baths have better throwing power than acid baths.

It is theoretically impossible to deposit metal in the apex of any sharp angle, and this is confirmed in TABLE 1. However, sharp internal angles do fill in with electrodeposits of sufficient thickness. The mechanism by means of which this occurs is shown in *Fig.* 5. Columnar crystals grow out from the sides of the angle to meet in a cleavage plane bisecting the angle. The strength of the metal in such a cleavage plane is very low. This condition can best be avoided by use of a fillet at the apex of the angle.

Our experience indicates that the following approximate rule applies: A fillet whose radius is equal to or greater than the thickness of the electrodeposited metal will prevent the formation of a cleavage plane in the apex of an internal angle. *Fig.* 6 illustrates the geometric basis for this rule. It shows also that if the deposit is thicker than the radius of the fillet, a cleavage plane will form in the portion of the deposit in excess of this thickness. Such a "combination" deposit in an angle will naturally be stronger than one with no sound deposit in the angle. An actual electrodeposit that has a structure as described is shown in *Fig.* 7.

Two hypothetical matrices illustrating the above discussion of angles are shown in *Fig.* 8. A deposit on *Fig.* 8*a* would be weak along *wxyz*. However, this weakness is compensated by high strength along *wz*. A deposit on matrix *b* would be weak all around *wxyzw*, and therefore a fillet is desirable if significant joint strength is needed. If a part with a design like *b*

**Table 1—Deposit Distribution on Angles***

Solution: Acid copper sulfate
Current Density: 10-40 amp/ft²
Length of side of angle: ½ inch

| Radius of Inside Fillet at Apex (Inch) | Ratio of Thickness at Apex to Thickness ¼-inch from Apex 45° | 90° | 135° |
|---|---|---|---|
| **Deposits on Inside Surface of Angle** | | | |
| 0.008 | 0.0 | 0.0 | 0.8 |
| .064 | .6 | .8 | .6 |
| **Deposits on Outside Surface of Angle** | | | |
| 0.030 | 1.8 | 1.8 | 1.5 |
| .086 | 1.7 | 2.0 | 1.4 |

*Data from work of Kronsbein and Morton, American Electroplaters' Society Research Project No. 11. *Proc. AES*, 1949, Page 229.

requires both strength and a sharp corner, a substantial thickness of metal can be first deposited in the corner, following which a fillet can be formed with solder, sprayed metal, low-melting alloy, or plastic. A sound deposit can then be built up over this fillet. The cross-section of such a corner is shown in *Fig.* 9.

Sharp outside angles do not present as difficult a problem in electroforming as do sharp inside angles and can be employed if needed. However, if not essential, replacement by rounded off contours may result in lower costs in the electroforming operation, through elimination of thieving, intermediate machining, etc.

In addition to the above rules on angles and recesses, the following points should be considered by the designer:

1. Certain combinations of metals as parts of the same matrix may present difficulties. For example, plain steel inserts or joining pins are just as susceptible to attack by an acid copper solution as are other parts of the matrix. This is often overlooked by the designer or machinist who places such inserts in a matrix made mainly of an inert material such as stainless steel.

Copper or brass inserts in an aluminum matrix cause difficulty in preplating processing. All combinations of this sort cannot be discussed here, but if such combinations are contemplated, the designer is advised to consult with the electroformer regarding their suitability.

2. The design should include some sort of "handle" on the matrix. For example, a waveguide matrix requires extra unplated length to provide a reference point for machining the outside surface. A handle may also serve as a means for suspending the matrix in the plating bath and as a means for making electrical contact.

3. In the case of permanent matrices, provision should be made for applying a separating force, for example, by means of a screw or an arbor press.

4. In the case of soluble matrices, provision for circulating the dissolving agent through the matrix will greatly increase the speed of dissolving. Thus, an aluminum matrix for a waveguide should be drilled with a hole extending its full length.

5. As an approximate guide, it may be stated that average deposit thickness can be controlled to $\pm 10$ per cent. If the shape is simple, thickness variation from point-to-point may also be held within $\pm 10$ per cent but if it is complex, the thickness may vary several-fold between thick and thin areas.

6. The designer should consult with the electroformer at the earliest possible stage of the design.

**Metal Selection:** Twenty-two pure metals can be plated from aqueous solutions. For various reasons, such as undesirable physical properties, or inability to obtain satisfactory thick deposits with presently known baths, only four of these are commonly used for electroforming. These are copper, silver, nickel, and iron. Some of the physical properties of these metals, as electrodeposited and after annealing or heat-treating, are shown in TABLE 2. One of the advantages of electroformed metals is that physical properties can be varied over a fairly wide range by simply changing the conditions of deposition, such as solution composition, current density, temperature, and addition agents. Physical properties can be further controlled by annealing, or, in the case of iron, by case-hardening. However, the latter treatments may lead to dimensional distortion.

Included in TABLE 2 are some data on stress in electrodeposits. Positive values in this table represent contractile stress. A contractile stress is present in most electrodeposited metals, and this may lead to subsequent dimensional changes. For example, it has been determined that stress causes a linear shrinkage of nickel electrotypes of about 0.1 per cent. Considerable work has been done to develop methods for reducing stress in nickel deposits.

There are practically no published data on the effect of stress on the dimensions and stability of electro-

**Table 2—Typical Physical Properties of the Commonly Used Electroforming Metals**

| Metal | Plating Solution | Tensile Strength (lb/in.$^2$×10$^{-3}$) | Ductility (% elong. in 2 in.) | Hardness (VPN) | Stress (lb/in.$^2$×10$^{-3}$) |
|---|---|---|---|---|---|
| Copper | Acid sulfate | 34–68 | 33–48 | 42–83 | Low |
| | High-speed cyanide | | 12–19 | 60–90 | Low |
| | with periodic reverse current | ..... | ..... | 100–220 | Low |
| Silver | High concentration, high-speed cyanide | 34–48 | | (Rockwell 15W) | |
| Nickel | Watt's (soft) | 60–80 | 10/30 | 140–250 | 3–40 |
| | All chloride (medium hardness) | 90–135 | 4–17 | 200–350 | 30–55 |
| | Ammonium salt type (hard) | 140–160 | 4–9 | 350–500 | 33–54 |
| Iron | Ferrous ammonium sulfate | 113 | 0–3 | 180–350 | ..... |
| | Hot ferrous chloride | 55–80 | 15–25 | 135–220 | ..... |
| | Annealed at 900° C | 35–47 | 25–40 | 50–90 | ..... |
| Cobalt-tungsten alloy | As plated | 120 | 0–slight | 330–620 | ..... |
| | Heat treated | ..... | Ductile if heated above 900° C | 250–1000 | ..... |
| Cobalt-phosphorus alloy | As plated | 130 | 0–7 | 350–700 | 26–36 |
| | Heat treated | ..... | 0 | 500–1100 | ..... |

formed parts. There is some evidence that thick deposits, when constrained from moving, as is the case when deposited on a rigid matrix, undergo self-relief of their stress during deposition.

In addition to its possible effect on dimensions, high stress in an electroformed part makes its removal from the matrix difficult because the stress, being contractile, shrinks it against the matrix. This statement does not apply to the cases where the part is electroformed against a flat matrix or on the inside surface of a matrix.

If precautions are taken to obtain deposits with the lowest possible stress, dimensional changes resulting therefrom are probably negligible.

Iron electrodeposits from the commonly used baths are stressed to about the same extent as nickel. The degree of stress usually present in copper and silver deposits is negligible.

Other pure metals which could be used if their properties are needed include gold, zinc, lead, antimony, and chromium. Some of these have distinct limitations. For example, it is difficult to plate thicknesses of more than a few thousandths of an inch of gold, so gold is most likely to be useful as a lining or coating for an article made mostly of another metal. Antimony and chromium suffer from extreme brittleness.

In addition to these pure metals, many alloys can be electrodeposited. None have acquired an important place in electroforming. Several recently developed alloy deposits, including cobalt-phosphorus, nickel-phosphorus, and cobalt-tungsten, have high hardness and strength and are further hardenable by heat-treatment to obtain properties which may make them useful in certain applications. Their properties are also shown in TABLE 2.

Laminated metals are commonly used in electroforming and may have definite advantages. Thus, in waveguides, silver or copper can be used on the inner surface for electrical conductivity, backed by nickel or iron, for strength with low thickness. Parts which require corrosion resistance can be formed with nickel on the inside and outside surfaces with iron sandwiched in between, to reduce cost or to conserve scarce nickel. Many such opportunities for advantageous use of laminates will occur to the designer who is aware of this construction.

One other metal that should be mentioned is aluminum. It cannot be deposited from aqueous solution, but nonaqueous solutions have recently been developed at Battelle Memorial Institute and at the National Bureau of Standards, from which thick, sound deposits can be made. Difficulties remain which render electroforming with aluminum impractical for large production at the present time, but small numbers of small items can be made if the need justifies the cost. Future improvements in the practicability of aluminum plating can be expected.

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# Stitched Fiber Replaces Sheet Metal

HEAVY-DUTY thermoplastic fiberboard is being used to replace sheet metal air ducts in automobiles. Wire stitching is used not only to fasten fiberboard pieces of the ducts together but also to attach sheet metal parts to fiberboard and metal to metal by Woodall Industries Inc. The fiberboard is heated and die formed before being stitched.

A heater distribution duct, *Fig.* 1, is the most complicated assembly presently produced by the firm. Three separate metal stitching operations, followed by a sealing stitch are required in the production of this assembly—metal-to-metal, felt-to-metal and a metal-to-fiberboard stitch. Stitching is also used to secure the spacers providing the outlet air gap.

Fig. 1—Metal-to-metal, metal-to-fiberboard and felt-to-metal stitching are used in production of this heater distribution duct

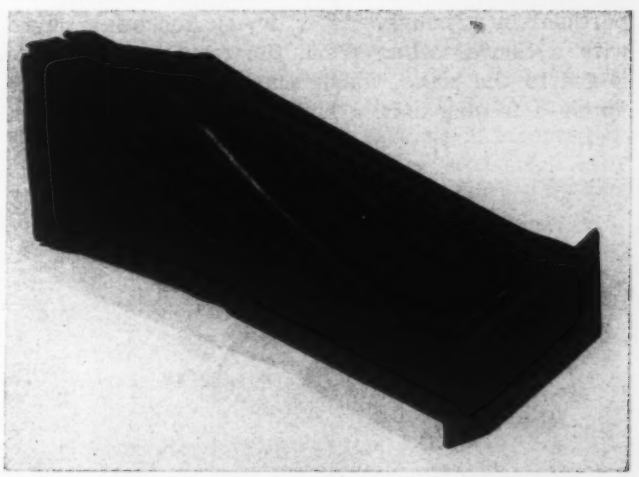
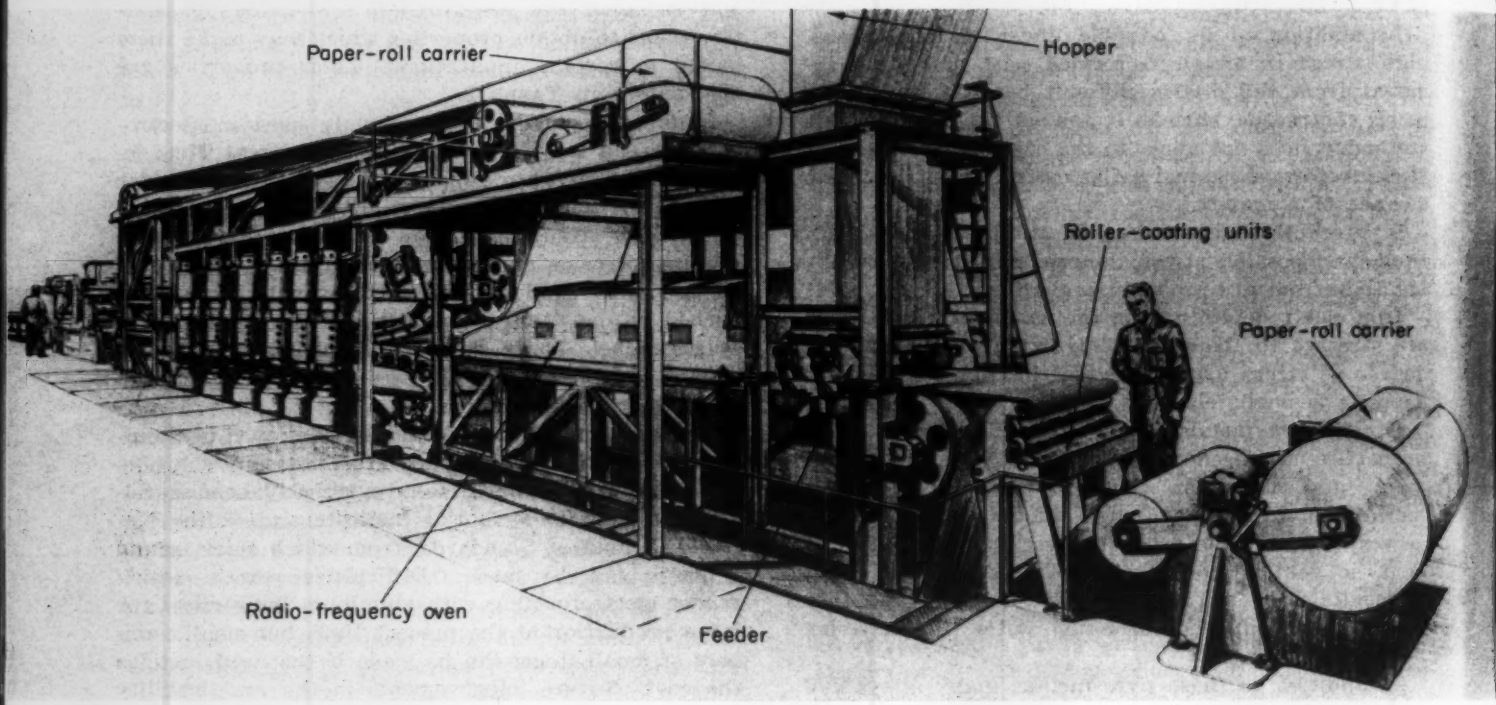


Fig. 2—Metal collar stitched to this fiberboard duct permits bolting to an automobile fire wall

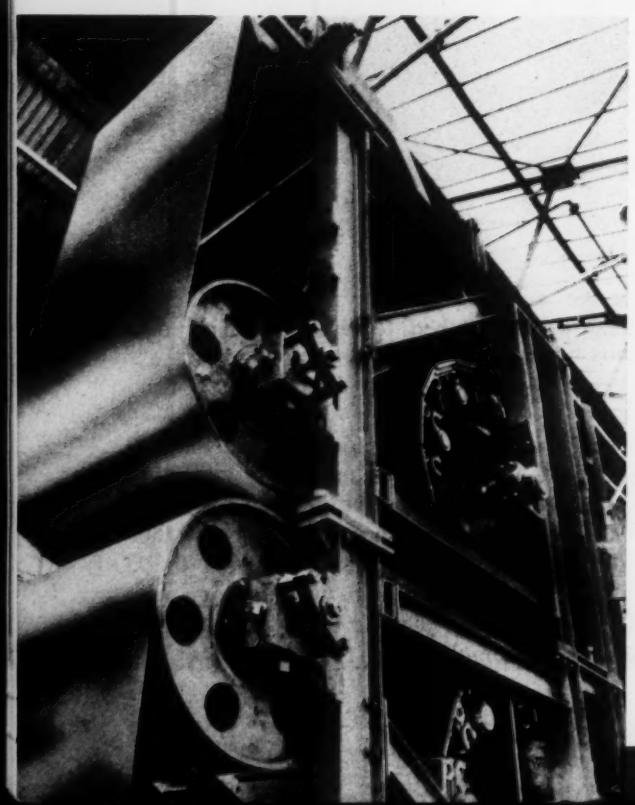
A heat exchanger-to-dash duct, *Fig.* 2, is made from two 0.093-inch thick fiberboard sections stitched together. A 0.065-inch thick, rubber-covered, metal collar is than fastened to the duct with 18-gage wire stitches. The metal collar permits bolting the duct to the fire wall of an automobile.

# Huge Press Pro

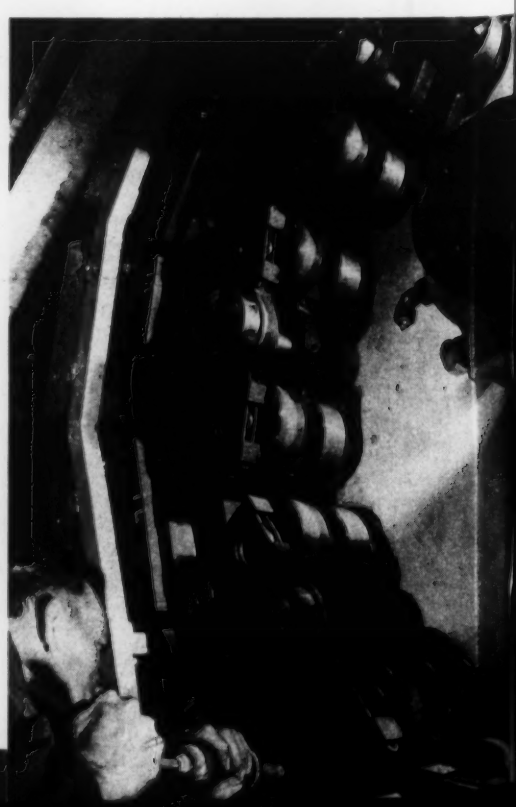



SAID TO be the first machine in the world for continuous production of building board, the huge Bartrev press recently built by Vere Engineering Co. in England will turn out between 25 and 40 million square feet of 4-foot wide board annually. Wood waste—cuttings, tops and branches as well as sawmill waste wood—is converted to particles by grinding. After drying and being mixed with a thermosetting resin, the resin-wood mixture is fed to the press, which consists of four separate units—a feeding unit, a high-frequency heating unit, the press itself, and an automatic saw. Heat and pressure cures the mixture into continuous hard board.

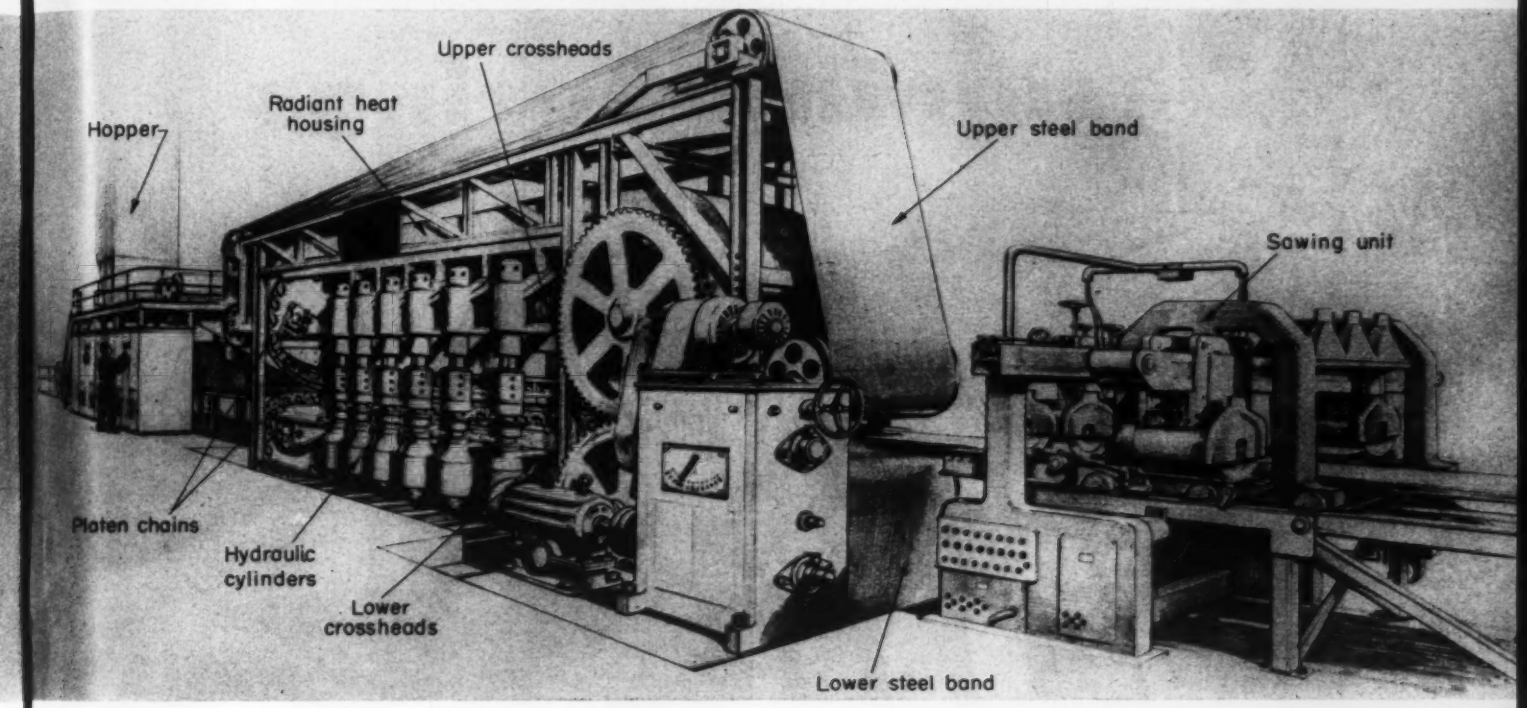
An "electronic eye" controls level in the hopper, and an automatic feeder lays a continuous carpet to any required uniform thickness on the lower of two endless stainless-steel bands. If desired, the carpet can be laid on paper facing; a second facing is then laid on top after the raw material has passed through the radio-frequency unit. The mixture is preheated to 85-90 C in the radio-frequency unit to control moisture content.



Four steel drums carry each of the polished steel bands. Tension applied to the bands and screw adjustment of the drums keeps the bands parallel at all times and provides for contraction of the bands on cooling to limit the risk of overstressing either the bands or the drums. Platens and platen chains back up the bands.



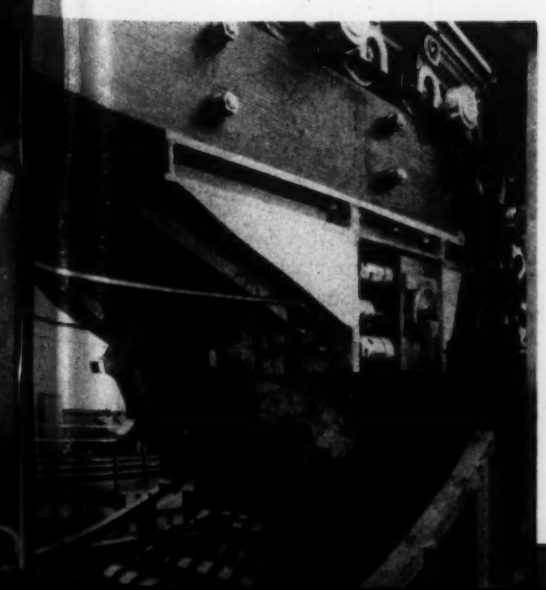
# ro duces Board by Continuous Process

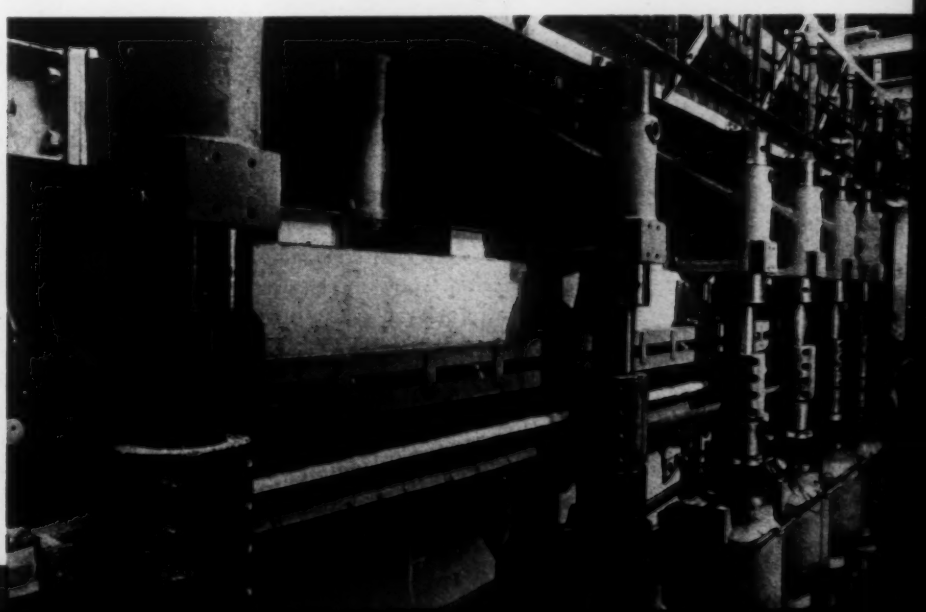



The carpet then goes to the continuous press, consisting of two endless heated platen chains and the two polished stainless-steel bands face to face—one above the other. An assembly of hydraulic cylinders provides the pressure to compact the mixture. The final heating stage, which cures the resin during compacting, is effected by heat transfer from the platens, heated by radiant heaters. A temperature of 110 to 115 C is maintained by thermostatic control until the raw material leaves the pressure zone as fully cured, fully compressed board. Automatic saws then trim both edges and square-cut the moving board.

The platen chain is driven by driving sprockets at the delivery end; idler sprockets at the feed end are adjustable for tensioning. Each platen has a set of roller bearings which ride on the compression-surface members, which are continuous within the pressure zone. Exterior wheels running within guide rails maintain proper horizontal positioning and help guide the chains at each end. The drive—an electric motor and gear box—provides speeds of 4 to 30 feet per minute depending on material, thickness and density.

Pressure loading is carried through six upper and lower cast-steel crossheads to the compression members and from there to the roller bearings on the platens. Each pair of crossheads is mounted on a vertical steel column, the upper crosshead being fixed and the lower crosshead capable of limited vertical movement. Hydraulic cylinders at each end of the lower crossheads provide the pressure to compact the board by holding the lower crossheads against adjustable limit stops.

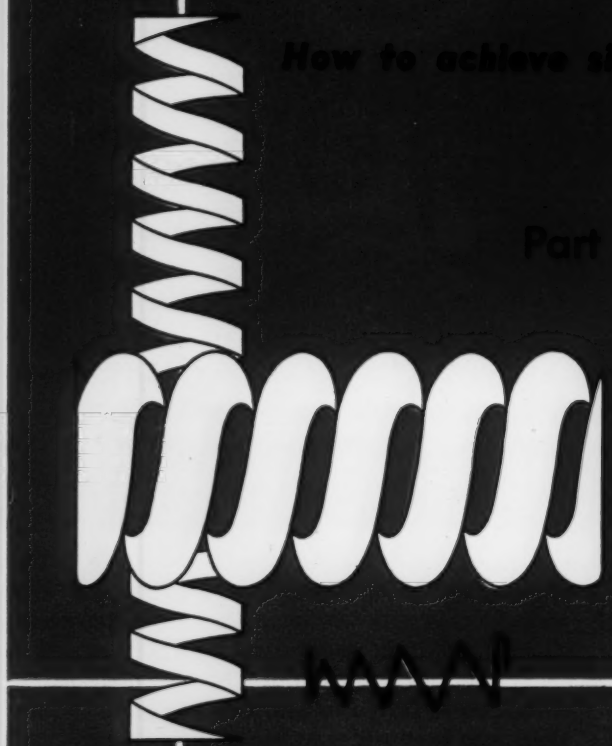




# Designing Springs

## How to achieve simplification and reduce costs

### Part 1—Compression Springs



By Stanley L. Albright
Design Engineer
Hunter Spring Co.
Lansdale, Pa.

MOST designers recognize the often painful fact that mechanical design is a compromise between optimum performance and lowest cost. Fatigue life must be reduced, larger operating variations tolerated, less effective materials used and possibly a favorite operating feature or two eliminated in order to cut the excessive production cost of the original model. Yet one of the major contributions to excessive cost is unnecessary in the first place—wasteful and careless design which might have produced equally good or better performance at lower cost. The value of designing for lower cost applies particularly to the design of springs, one of the most common components in mechanical design.

The basic approaches to design for lower cost are best demonstrated by reviewing a number of specific designs which represent common problems and their solutions. In this article, first of a three-part series, attention will be devoted to compression springs and the important cost factors influencing their design. Succeeding parts will consider extension and torsion springs separately. Although many elements of good design practice apply to all three of these fundamental types, each involves its own peculiar methods of treatment.

## SELECTION OF SHAPE

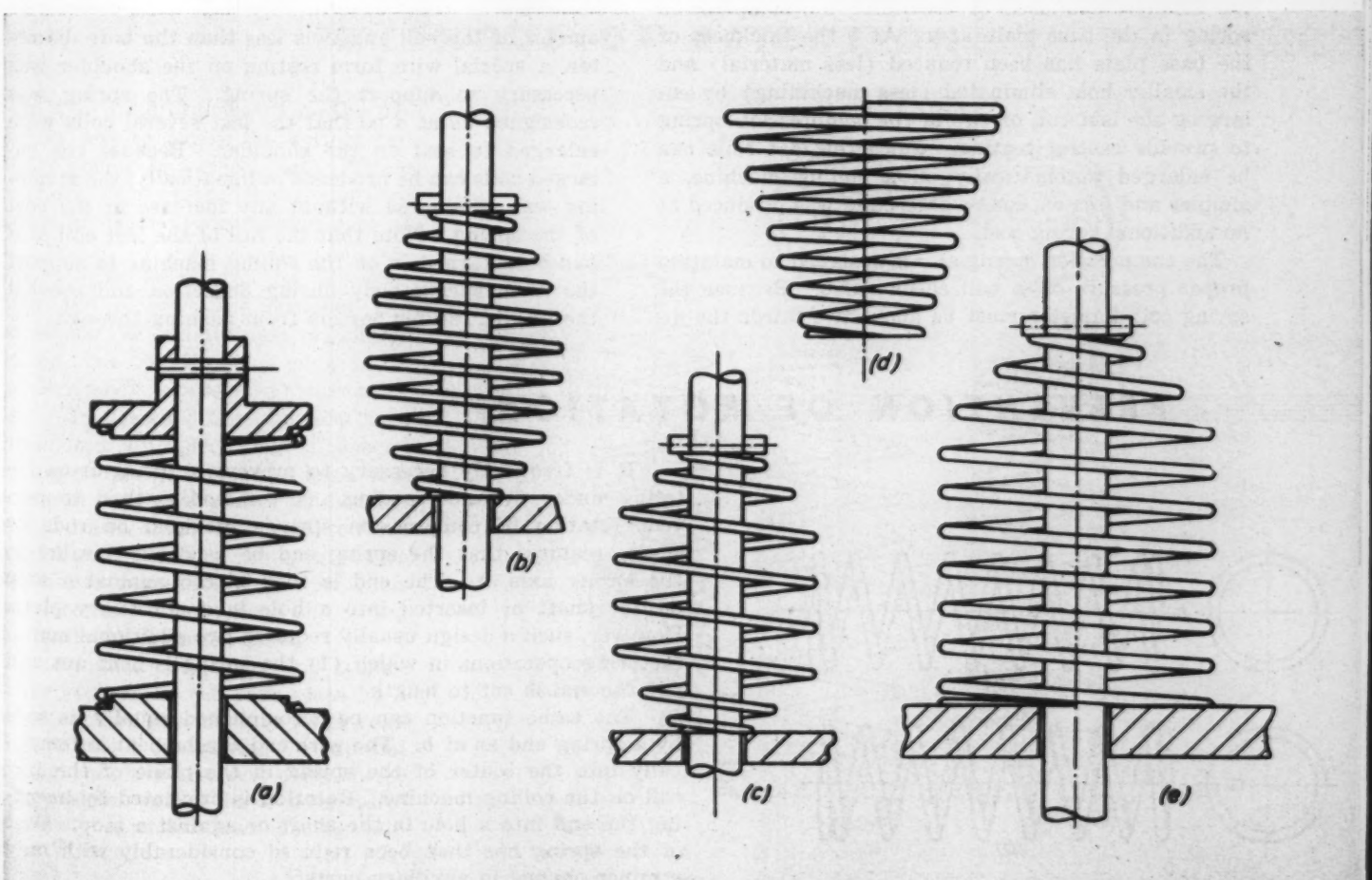
In the design shown at *a*, a helical compression spring encircles a shaft and is mounted between two screw-machine parts. With the top part secured by a pin through the shaft, the spring reacts against a vertical force on the bottom part. Whatever the dimensions of the spring or the screw machine parts, it is safe to assume that the cost of materials and machining of the two parts far exceeds that of the spring which they are provided to seat.

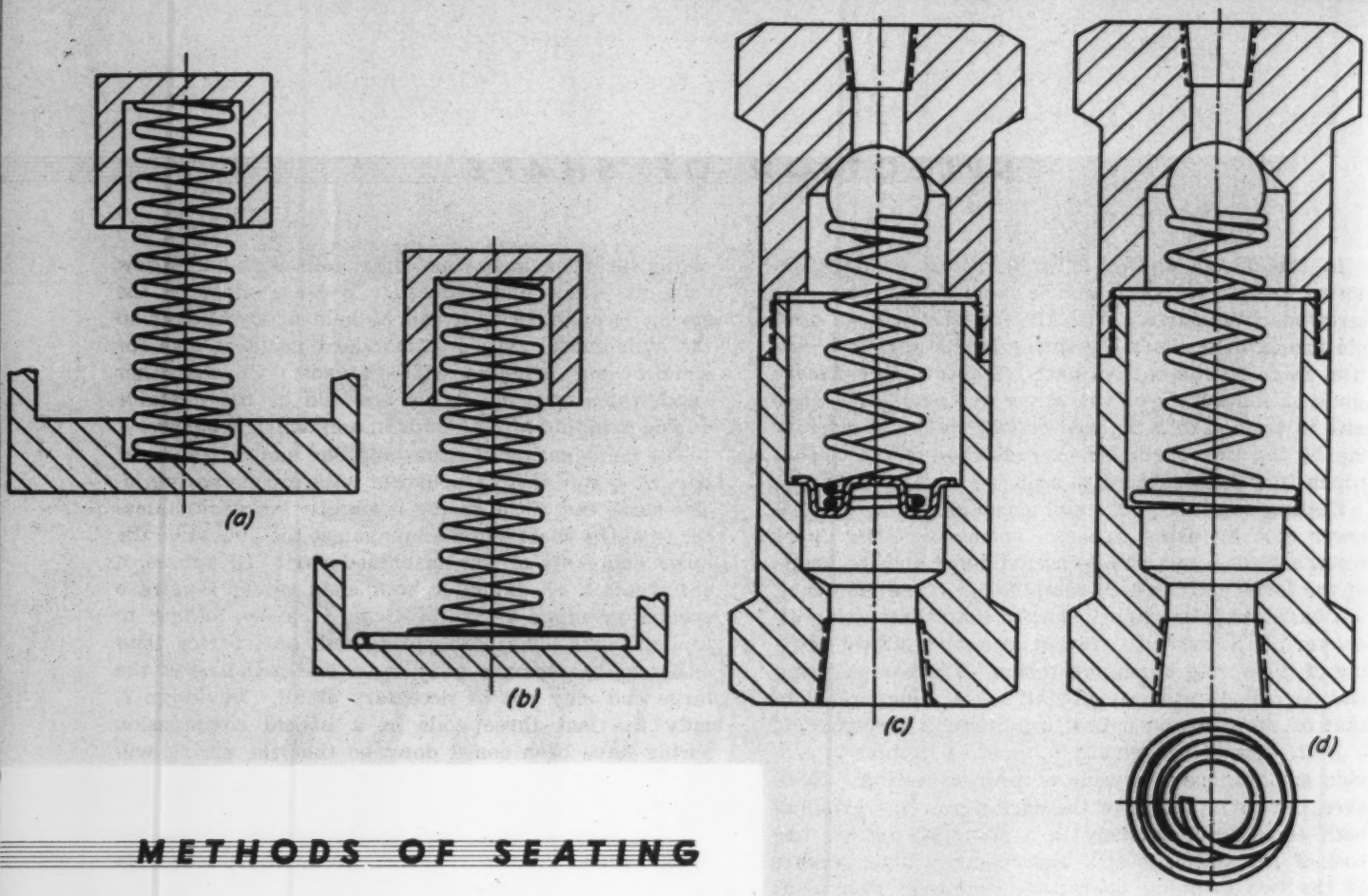
Seating can be equally well accomplished at a much lower cost by using a barrel spring, *b*. The upper screw machine part has been eliminated and the shape of the lower part greatly simplified. The diameter of the barrel ends is slightly larger than the outside diameter of the shaft to prevent excessive lateral shifting of the spring during operation. The barrel spring can be coiled automatically at a cost comparable to that of the common helical compression spring, *a*.

Both ends of the spring, *b*, must be ground to provide smooth, parallel ends of proper seating. However, the barrel shape of the spring prevents grinding both ends simultaneously in a standard fixture; the cost of the spring is still unnecessarily high because of the two grinding operations required. Most coils of the spring, *c*, have equal diameters, with only a few coils at either end reduced. Because most of the spring is cylindrical, it can be held firmly enough in the cylindrical cavities of standard grinding dies for simultaneous grinding of both ends. On the other hand, the barrel spring at *b* would be too unstable during grinding of both ends in a cylindrical fixture.

The combination of a pin and one simple machined part at *b* can also be achieved with a cone spring, *d*. The small end of the spring is slightly larger in diameter than the shaft and fits up against the pin, while the large end rests on the machined part. Of course, a specification on grinding both ends would require a special grinding die with a coned cavity, adding to tooling cost. The cone spring will seat better than either of the springs at *b* and *c* and grinding of the large end may not be necessary at all. In design *e*, only the last three coils of a helical compression spring have been coned down so that the spring will be securely held in a cylindrical die for grinding both ends.

It is very evident that proper spring design can simplify and reduce the cost of auxiliary parts as well as the spring itself.



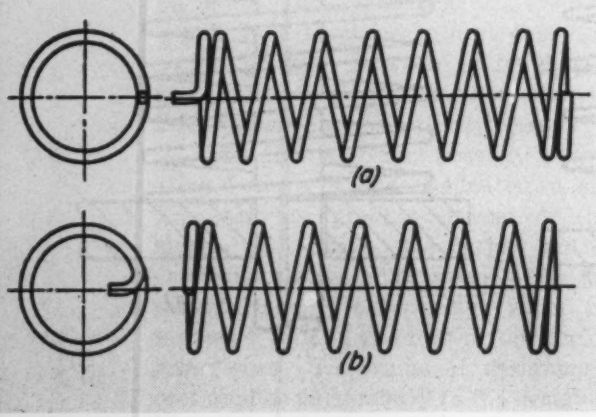



## METHODS OF SEATING

A special machining operation was required to drill the smaller hole used to centralize the compression spring in the base plate at *a*. At *b* the thickness of the base plate has been reduced (less material) and the smaller hole eliminated (less machining) by enlarging the last coil or two of the compression spring to provide central seating. Since the last coils can be enlarged automatically on a coiling machine, a simpler and less expensive base plate was produced at no additional spring cost.

The compression spring at *c* is designed to maintain proper pressure on a ball check valve. Because the spring coil diameter must be about two-thirds the diameter of the ball and thus less than the bore diameter, a special wire form resting on the shoulder was necessary to support the spring. The spring was redesigned as at *d* so that the last several coils were enlarged to seat on the shoulder. Because the enlarged coils can be produced automatically, the stamping was eliminated without any increase in the cost of the spring. Note that the tail of the last coil at *d* has been turned in on the coiling machine to support the main spring body during deflection and prevent the smaller, stiffer portion from pushing through.

## PREVENTION OF ROTATION

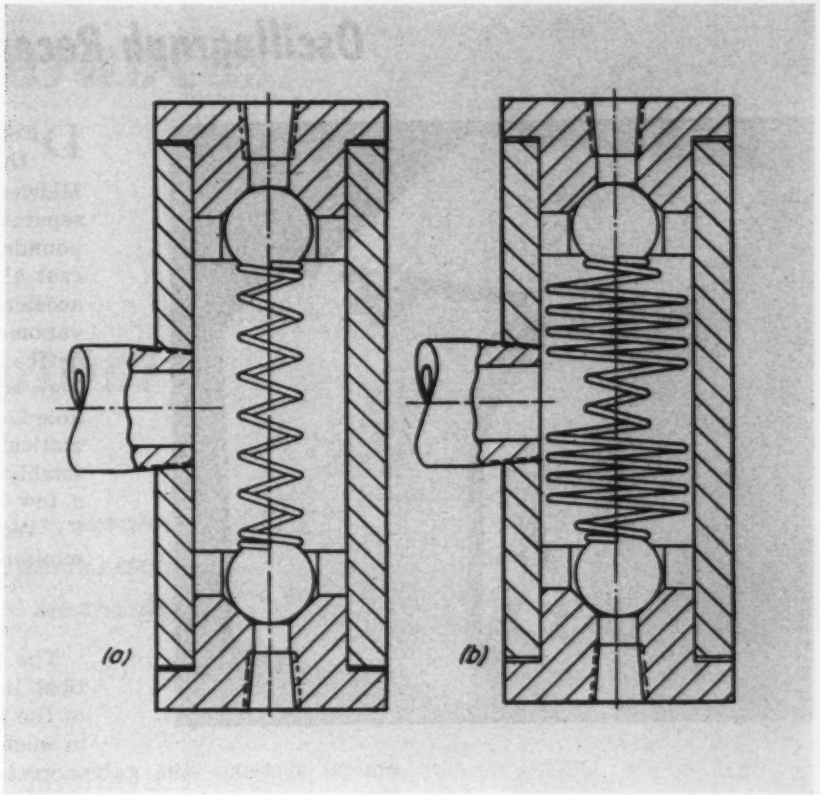



It is frequently necessary to prevent a spring from rotating under dynamic loading. A common method to prevent rotation of compression springs mounted on rods or shafts requires that the spring end be bent out parallel to the spring axis, *a*. The end is then placed against a stop on the shaft or inserted into a hole in a stationary plate. However, such a design usually requires two additional manufacturing operations in which (1) the spring is bent out and (2) the end is cut to length.

The same function can be accomplished equally as well by a spring end as at *b*. The wire end can be bent automatically into the center of the spring in the plane of the last coil on the coiling machine. Rotation is prevented by inserting the end into a hole in the shaft or against a stop. Cost of the spring has then been reduced considerably with only a minor change in auxiliary parts.

## ELIMINATION OF BUCKLING

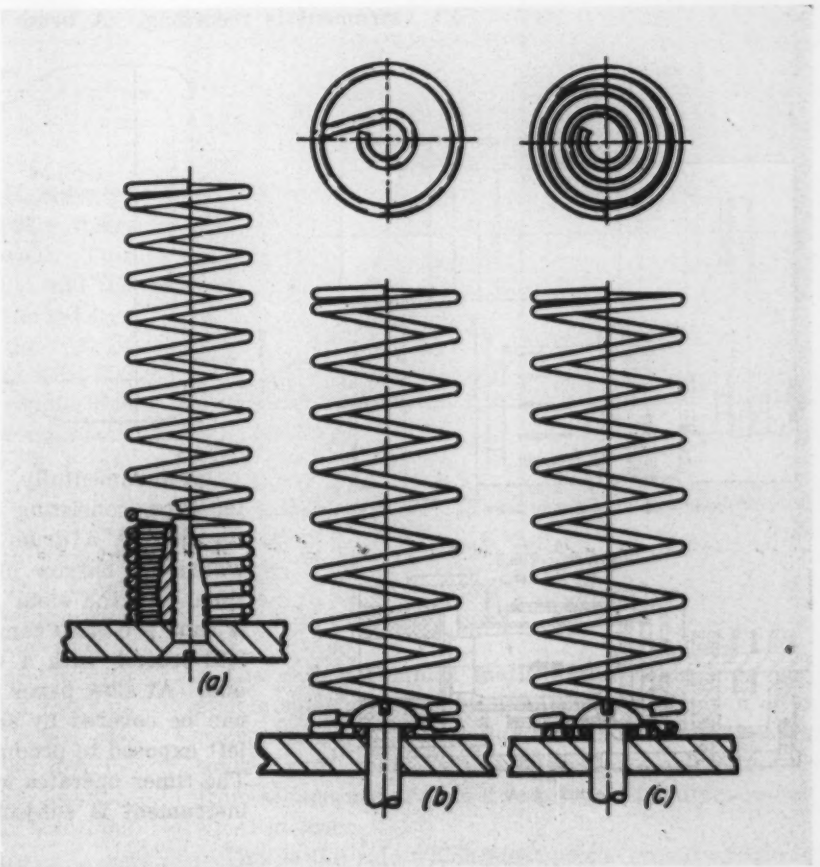
It was necessary to provide spring mounting for the two ball checks in a valve, *a*, without unduly obstructing flow through the connecting pipe. The first and most obvious solution was to specify a common helical compression spring as shown. However, it took little time for the designers to discover that the spring was not stable and buckled in the assembly. The problem was solved as at *b* simply by enlarging the diameters of most coils to nearly the inside diameter of the shaft. The end coils are still small enough to fit the balls and several coils at the center of the spring also have small diameters so as to reduce the obstruction to horizontal flow in that area. The four changes in coil diameter were achieved automatically on the coiling machine, thereby producing a spring that appears complicated but is little more expensive than a comparable compression spring of constant coil diameter.




## METHODS OF RETENTION

In the design shown at *a*, the objective was to secure the bottom end of the spring to a metal plate. Three methods of securing the spring are given in order of decreasing cost at *a*, *b* and *c*. In design *a* the compression spring is secured on threaded plug and screw. The designer has succeeded in maintaining a simple spring, but the threaded plug is an unnecessarily expensive accessory part. In design *b* the plug has been eliminated by specifying a special spring end to fit under the head of a screw in the metal plate. The spring end is drawn out from the coil to form a hook at the axis of the spring. Two additional manufacturing operations are necessary to (1) bend the spring end and (2) form the hook.

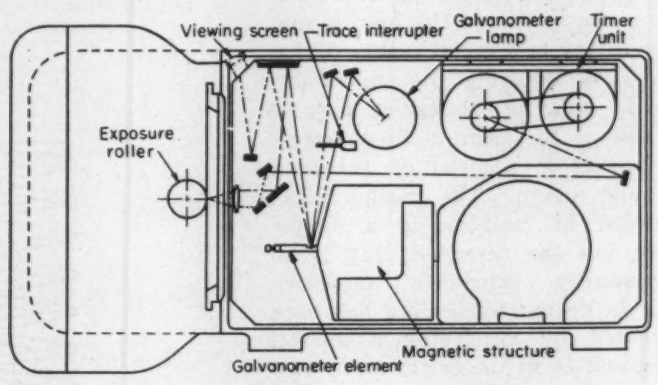
In design *c* the spring end is similarly secured to the base plate by a screw, but at considerably lower cost. Rather than specifying a special spring end, the last few coils of the compression spring have been automatically spiralled-down during coiling.

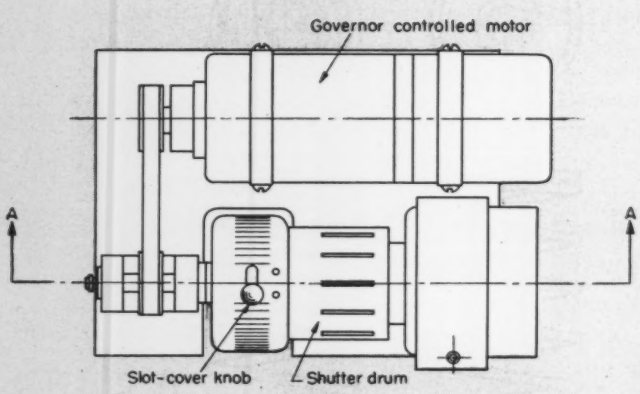


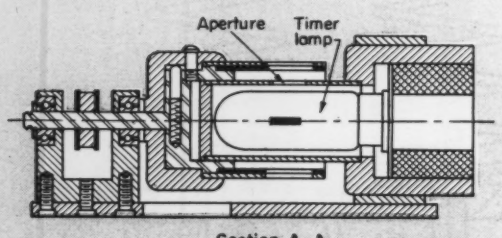
# Oscillograph Records 14 Channels of Data

DESIGNED to resist high acceleration forces, the model 580 flight-test oscillograph of Midwestern Geophysical Laboratory records 14 separate channels of data—yet weighs only 20 pounds. One feature of the instrument is its cast aluminum-alloy construction which permits accelerations up to 25*g* if shock-resistant galvanometers are used. A shutter-type timing device operates with excellent accuracy even at high acceleration. Recording speeds are adjustable from ½ to 44 inches per second. A thermostatically controlled galvanometer magnetic assembly keeps galvanometer temperature within a few degrees of any preset valve (usually 100 F), reducing galvanometer drift to an absolute minimum even at temperatures as low as −65 F.

The folded optical system increases the optical arm and hence the apparent sensitivity of the galvanometer over that normally obtained in such a compact instrument. Three separate optical systems—the galvanometer system, the viewing system, and the timing system—are excited from two sources. The galvanometer system is split so that part of the light leaving each galvanometer-element mirror is directed to the external viewing screen and the remainder to the recording medium. Thus, dynamic trace position is viewed on a full-width screen at a one-to-one ratio to the recording trace while the instrument is recording. A beam interrupter identifies each trace.




Fundamentally, the timing mechanism is of the shutter type, consisting of a governor-controlled 28-volt dc motor driving a drum with ten equally spaced slots, nine of which are narrow and one wide. The drum rotates at 600 rpm. As the slots pass an aperture, a narrow timing line is thus produced completely across the recording paper every 0.01-second, with a wider line being produced every 0.1-second. At slow paper speeds nine of the ten slots on the drum can be covered by shifting a small knob; one narrow slot is left exposed to produce a narrow timing line every 0.1-second. The timer operates within 2 per cent accuracy even when the instrument is subjected to high lateral acceleration.

# Assigning Tolerances for Maximum Economy

***. . . a statistical procedure for obtaining maximum profit at a given performance level in precision mechanisms***

By Eugene W. Pike and Thomas R. Silverberg

*Radar and Communications Div.*
*Raytheon Mfg. Co.*
*Waltham, Mass.*

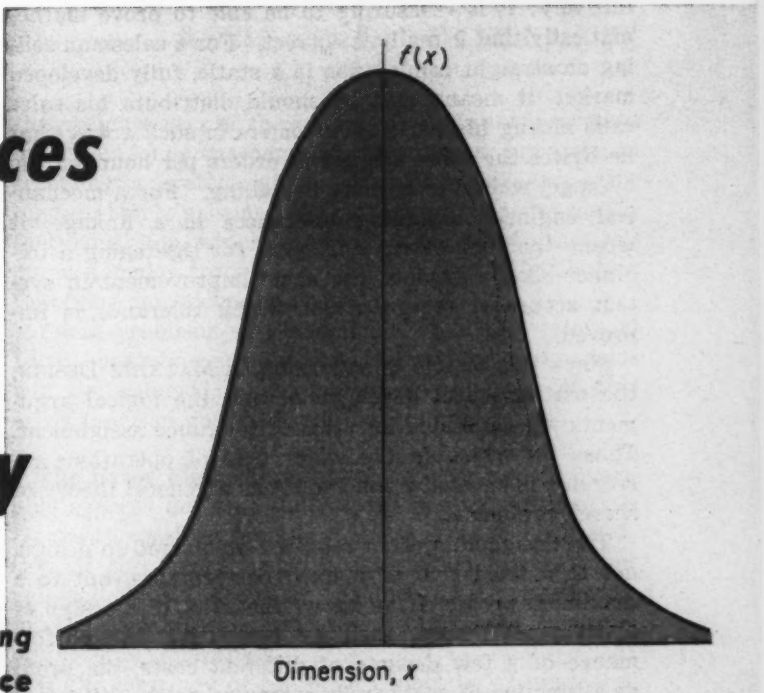
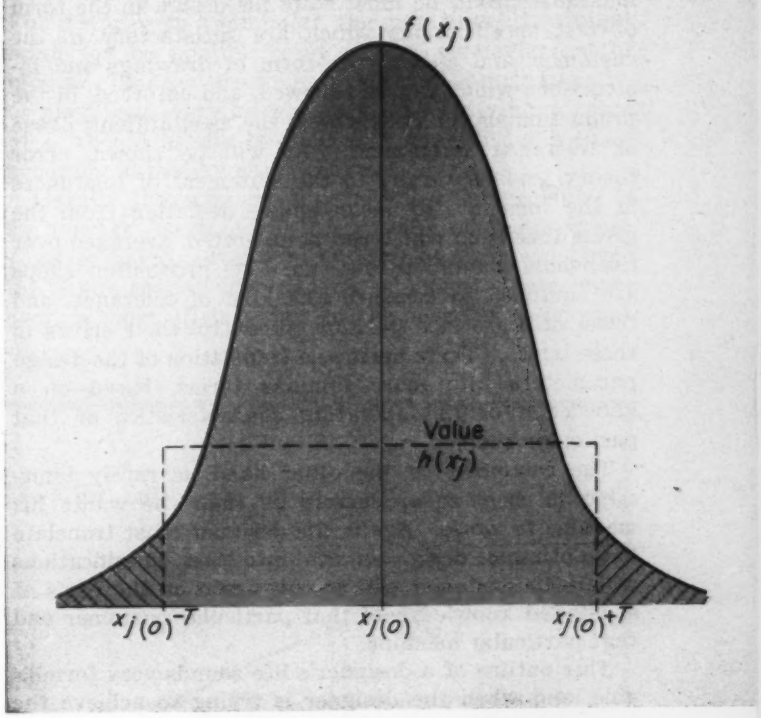



Fig. 1—Above — Curve of normal distribution

Fig. 2—Below—Value curve and tolerance limits




IN CONNECTION with the design of a large accurate mechanical linkage, the authors were recently obliged to develop the theory of assigning tolerances with somewhat more care than is usual. This theory proved to be difficult mathematically, and the numerical calculations were laborious, but the savings were impressive—roughly 15 per cent of the cost of each linkage. Although mechanical designs with 300 critical dimensions fortunately are still rare, the line of reasoning is applicable to many simpler questions in mechanical design. Further than that, it is applicable to many operating problems of the type which operations research specialists call "search" problems. By these are meant problems dealing with the best allocation of a limited amount of effort (cost, time, manpower, etc.) to a number of competing tasks.

It may seem strange at first that the best way to assign tolerances to a mechanical structure is also the best way to assign salesmen to territories, or ships to antisubmarine duty. It is less strange when one reflects that each of these questions involves distributing an inadequate effort as effectively as possible. Electric power companies have used similar solutions of load distribution problems for many years.

The rather complex mathematics leads to a very simple rule for distributing any fixed amount of effort over a variety of tasks: Buy results from the cheapest source until there is no cheapest source; then buy from all sources at such a rate that all sources remain equal in price.

This is the rule which most people would choose in-

tuitively; it is reassuring to be able to prove mathematically that it really is correct. For a salesman selling on straight commission in a static, fully developed market, it means that he should distribute his sales calls among his various customers in such a way that he writes the same amount of orders per hour, on the average, wherever he may be calling. For a mechanical engineer assigning tolerances in a linkage, it means that one extra cent spent for tightening a tolerance should produce the same improvement in system accuracy, regardless of which tolerance is improved.

Since this article is appearing in MACHINE DESIGN, the mathematical development and the logical arguments will be stated in terms of tolerance assignment. Those interested in the wider field of operations research will recognize much of it as a general theory of search problems.

The designer is often required or obliged to design, not to a fixed cost or a fixed performance, but to a maximum profit. If he knows the value of a design of given performance, then by computing the performance of a few designs of different costs, the profit as a function of cost can be computed as the difference between cost and value, and that cost giving maximum profit found from a curve sketched through these computed (cost, value) points.

Furthermore, the designer must not only design to maximize profit, he must state his design in the form of test specifications which are satisfactory to the customer, and also in the form of drawings and instructions which can be followed, and enforced, in the production shop. This is often the most difficult phase of tolerance assignment. As will be shown, error theory leads naturally to the statement of tolerances in the form of the mean-square deviation from the given dimension which can be tolerated, averaged over the whole manufacturing run. Few production shops are equipped to measure this kind of tolerance, and fewer still are in a position to control their errors in these terms. There must be a translation of the design parameters into more familiar terms, based on a knowledge of the operating characteristics of that particular shop.

The customer, on the other hand, is rarely interested in mean-square errors as such—he wants his machine to work. Again, the designer must translate his optimum design errors into test specifications which the customer will accept, again on the basis of a detailed knowledge of that particular customer and that particular machine.

This outline of a designer's life sounds very formidable, and when the designer is trying to achieve the utmost that his technology permits, it is formidable. There is no more reason for astonishment or apology about the intricate mathematics of tolerance assignment than there is for astonishment or apology for the intricate mathematics of gas turbine design.

Strictly speaking, the theory which follows applies only to open kinematic chains. The extension to closed, multiple closed, or overdetermined kinematic chains, which are the same in basic principle, has not been carried through in detail.

**Linear Propagation of Small Errors:** A designer cannot specify directly, in the drawings which he sends to the manufacturing shop, the performance or the accuracy of the product manufactured according to his specifications. The most that can be specified are the dimensions of the individual elements, and the tolerable deviations from these dimensions in manufacture. These errors in the individual dimensions combine, in a random statistical process, into the errors of the manufactured units. Since those finished instruments whose errors are too great must be scrapped or reworked, it is evidently a wise thing for the designer to calculate, so far as he can, the probable errors of the finished product before his plans are sent to be manufactured.

If $x_j$ is the specified value of the $j$-th dimension (as used in this presentation, "dimension" may mean not only a geometrical length between two points on a part, but also any quantitatively specified factor affecting the output, such as a resistance, a moment of inertia, or the density of a filling fluid), then the output or indication of the instrument, $x_o$, is some known function of the dimensions:

$$x_o = F(x_1, x_2, \ldots, x_j, \ldots) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

If there are small departures $\epsilon_j$ from the specified dimensions, then, to the first order of small quantities, the departure $\epsilon_o$ of the output from its expected or desired value is given by

$$\varepsilon_o = D_1\,\varepsilon_1 + D_2\,\varepsilon_2 + \ldots + D_j\,\varepsilon_j \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

where $D_j$ is the partial derivative $(\partial x_o/\partial x_j)$ calculated from Equation 1.

**Design Parameters versus Output:** If the designer could specify the actual individual errors $\epsilon_j$, he would simply specify them to be zero, and there would be no need for error analysis. The crux of the designer's problem is that he *cannot* specify individual errors, but only a much vaguer error parameter; an analysis of the exact means which a designer *can* use to control output error is the essence of this discussion.

The development of statistical quality control theory has made it clear that any specific manufacturing process, in addition to creating successive units having approximately some prespecified dimension, also has a characteristic associated error distribution. Briefly, the manufacturing process determines not the error in a specific part, but the probability that errors of a given size will occur. Such a functional relationship between the size of an error and the probability that it will occur is known as an error probability distribution, or, more briefly, an "error distribution $f(x)$." This is discussed in texts on statistical quality control; for instance a very good discussion is given by Shewart.[1]

A first step, then, is to set up an equation, parallel to Equation 2 between a set of error distributions, $f_j(x)$, over the individual dimensions of a system, and the resulting error distribution of the output, $f_o(x)$. The distribution resulting from the addition of a number of independent distributions can be formed in a number of ways; the most convenient for the present

1. References are tabulated at end of article.

purpose makes use of the fact that the cumulants[2] of the sum are simply the sum of the cumulants of the individual error distributions. Taking advantage of the fact that the central limit theorem[3] usually applies to practical engineering cases, one need sum only the first and second cumulants, since the remainder of the cumulants can be deduced from these two. The central limit theorem applies whenever a large number (roughly, more than 10) of independent distributions, having second cumulants of nearly the same size, are summed. These conditions are usually satisfied in engineering problems, but the designer must check each separate problem. Exceptional problems can be very misleading. Then, two equations are reached as the useful parallel, for distributions, of the linear error propagation Equation 2:

$$m_o = D_1 m_1 + D_2 m_2 + \ldots + D_j m_j + \ldots \quad (3)$$

$$\sigma_o^2 = D_1^2 \sigma_1^2 + D_2^2 \sigma_2^2 + \ldots + D_j^2 \sigma_j^2 + \ldots \quad (4)$$

In these equations, the more familiar mean $m$, and second moment $\sigma^2$, have been substituted for the first and second cumulants. As a rule, the means of the individual error distributions are zero, so that Equation 3 is not significant, but again, the designer should check in each individual case, since exceptions can be misleading here too.

The sums $m_o$ and $\sigma_o^2$ define the position and width of the output error distribution function, which is, if the central limit theorem applies, approximately normal. The shape of this normal distribution is illustrated in *Fig.* 1.

According to this argument, the prediction of output error from design specifications must take place through the appropriate weighted sums of the mean values and second moments of the error distributions on the individual dimensions. This circumstance embroils the designer in semantic difficulties, both with the ultimate user of the product (who is not interested in either fancy mathematics or excuses, but only in receiving a system which will never make an error bigger than a specified amount), and with the manufacturing shop, which feels with some justice that tolerances make trouble enough, let alone distribution functions and second moments.

These problems will be considered further later on. In the meantime, some acceptable working compromise will be assumed, and further consequences of this error function approach will be explored.

**The Error Field:** Many machine systems are "variable aspect" devices; that is, the partial differentials $D_j$ are themselves functions of the state or configuration of the device, usually determined by the input values. Thus the output variance $\sigma_o^2$ of the device, instead of being one number, is a variable in the space of the input quantities.

If the accuracy of the device must be expressed as a single number, the largest value of the second moment, or variance might be selected. In most cases, however, this value is not a good criterion of accuracy, because it will usually be found that this value occurs very seldom when the device is in actual operation. For instance, in a computer, the maximum error might occur, or be possible, only at one particular set of inputs. This set of inputs may never occur naturally, or may occur very infrequently. The maximum value of $\sigma_o$ should hardly be used as a yardstick of system accuracy in this hypothetical case.

Usually the most meaningful value for accuracy is an average, weighted by the density of expected use (and/or the importance of an error of given size) over the input space. The density of expected use, however, is most often known in the space of the output

Fig. 3—Cost curve for typical component

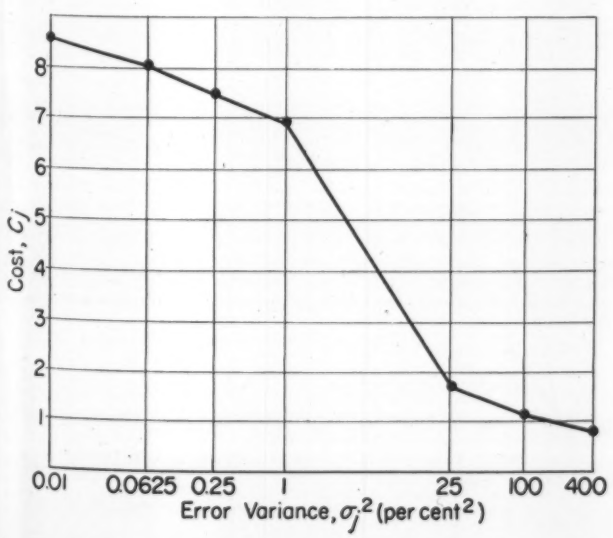
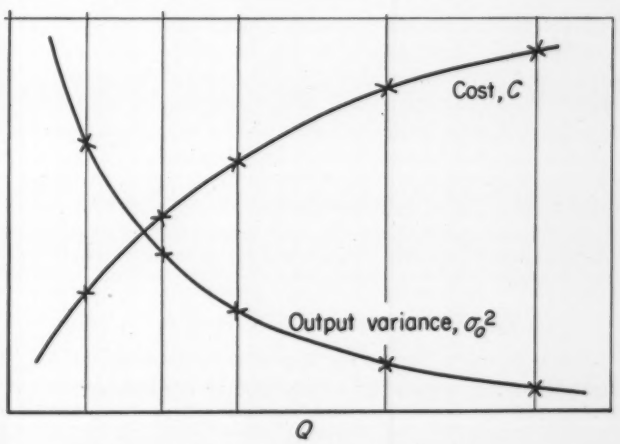



Fig. 4—Cost and output variance as functions of $Q$



quantity or quantities, and no one-to-one correspondence exists between input and output values. This makes the situation more difficult to handle, but a meaningful value for the accuracy can be found if reasonable care is exercised.

Whatever the method of rating the accuracy, the *test specifications* are essentially a prescription for taking samples from the predicted distribution of errors, and inferring from these whether the design has been correctly manufactured. It is assumed here that the design was accepted on the basis of predicted performance. The theory of statistical experiment-design can be used to balance the cost of tests against the costs of unfairly rejecting a good manufacturing operation, or unwisely accepting a poor one.[4, 5]

**Optimum Error-Assignment:** The next step is to consider the factors which enter into optimum distribution of assigned errors over the dimensions of a design. In order to do this, it is necessary to state the objective of the design with respect to accuracy as a value curve which describes quantitatively the value of any one manufactured structure, as a function of its output error. As an example, if the product is tested over its entire range, and rejected outside of tolerance limits, then the value curve will be constant between the rejection limits, and zero outside of them. See *Fig.* 2, where $x_{j(o)}$ is the desired zero-error dimension, and $x_{j(o)} \pm T$ are the tolerance or rejection limits.

It is also necessary to describe the manufacturing process by means of a series of cost curves, each one describing quantitatively, as a function of the error variance, the cost of manufacturing one of the dimensions of the design. This argument has been simplified by assuming that the mean errors of the various dimensions are zero. To establish these curves, even approximately, involves considerable study in some cases. An illustrative cost curve for a specific type of resistor is shown in *Fig.* 3. Curves of this type can be compiled fairly directly from catalogs, when one has some knowledge of the manufacturing process by which the component was made, but this is not true for all kinds of components. The necessity of using the error variance, rather than the tolerance, adds to the difficulties of an exact tabulation of such cost curves.

Any given choice for the specified variances $\sigma_j^2$ of the individual dimensions in a design leads to an output error variance

$$\sigma_o^2 = \sum_j D_j^2 \, \sigma_j^2 \qquad (5)$$

and a total cost

$$C_o = \sum_j C_j \, (\sigma_j^2) \qquad (6)$$

These are linear functions, sums over $j$. Note that this cost function, $C_j(\sigma_j^2)$, is a function which depends on the distribution of errors in a particular component, and not directly on the commonly used tolerance limit. In all cases, a tolerance limit will be greater than or equal to the corresponding $\sigma_j$. The optimum assignment of the $\sigma_j^2$'s is clearly that one which makes $C_o$ a minimum, for a fixed value of $\sigma_o^2$, or vice versa. Either problem is easily solved by the calculus of variations, and the answers are identical:

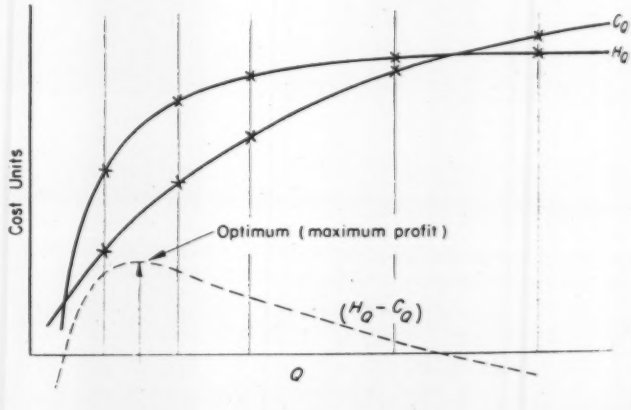
$$(\partial C_j / \partial \sigma_j^2) = Q \, D_j^2 \qquad (7)$$

where $Q$ is an arbitrary constant, independent of $j$. In words, Equation 7 states that, in the optimum design, the cost of reducing the output variance should be the same, no matter which component is improved. The factor $Q$ is then the cost of error elimination in dollars per variance unit.

In calculating minimum cost for a given output error, or vice versa, it is almost always easiest to select a reasonable value of $Q$, such as $\$X$ per (per cent)$^2$. Since $D_j$ is fixed by the design, Equation 7 leads to a value for the slope of the cost curve. Then, picking out this point gives values for $C_j$ and $\sigma_j^2$; summing over all dimensions gives the total cost $C_o$ and, through the $D_j^2$ factors, the total output variance $\sigma_o^2$. Repetition of this process for two or three further values of $Q$ will provide the data to give cost and output-variance curves as a function of $Q$, *Fig.* 4.

Since the basic idea behind this development is the determination of the economically optimum tolerances, it is necessary to convert the output-variance curve of *Fig.* 4 into economic terms for comparison with the cost curve. In those cases where the central limit theorem applies, this is easily done by constructing the normal distribution curve having the variance $\sigma_Q^2$ and the mean value given by Equation 3, and multiplying it point by point with the value curve. The integral of the product curve will be, then, the average value of a manufactured unit when the output variances are normally distributed with variance $\sigma_Q^2$ and mean $m_o$. This average value, $H_Q$, can then be plotted as a function of $Q$, with the cost curve $C_Q$ on the same graph, as shown in *Fig.* 5. The proper $Q$ is that one which corresponds to the maximum profit, $(H_Q - C_Q)$, as shown in *Fig.* 5 from similar profit curves for al-

Fig. 5—Profit chart



ternative designs, a more informed choice among designs may be made.

It is necessary again to emphasize the statement made in the introduction: it is rarely possible or profitable to carry through a complete and exact solution numerically. Informed estimates may be made for value curves, cost curves, and even for the propagation factors $D_j$. A rigorous qualitative application of the ideas presented will, in most cases, help the designer stay on the high road to a profitable design.

**Variances and Tolerances:** After optimum variances $\sigma_j^2$ have been assigned to the several dimensions in the design, it remains to set up a manufacturing operation which will generate the desired parts and dimensional variances at minimum cost. This is a difficult problem, largely because every variation in the organization of a manufacturing concern changes the parameters of the problem in one way or another. Some basic ideas do have general application, however.

First, there is only a very loose connection between tolerances and variances. Tolerances slice off the wings of the manufactured distribution, but different manufacturing conditions may change the variance associated with a given tolerance by an amount ranging from a few per cent to a factor of five. In *Fig. 6a*, $\sigma_1$ is the root-mean-square value of the width of that part of the distribution which will pass inspection; that is that part of the total distribution which lies between $x_o + T$ and $x_o - T$. Correspondingly, $\sigma_2$ holds for the distribution shown in *Fig. 6b*. In this case, the same tolerance limits, $\pm T$, applied to two different distributions, result in variances which differ by a factor of about four; $\sigma_1^2/\sigma_2^2 \approx 4$. If tolerances are used to control dimensional variances, the tolerances must be established on the basis of a reasonably accurate knowledge of the manufactured distribution on which they will operate.

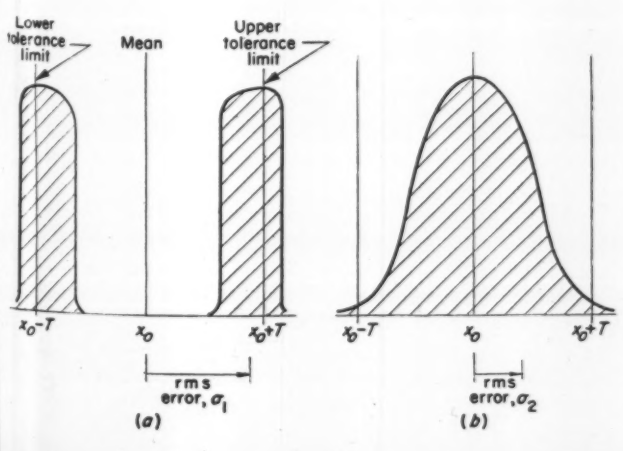



Fig. 6—Tolerance limits and standard deviations for two types of distribution

## ASSIGNING TOLERANCES

An alternative procedure, if large numbers of a particular item are to be made, is to inspect enough of the items which are made first to establish both the fact of statistical control and the form of the manufactured distribution. Then it is possible to set, by calculation, tolerance limits which will allow selection from the experimental distribution of a distribution of parts which will have the desired mean value and variance.

In a shop where individual machines are kept in statistical control, it may be possible to select for use that machine which has the desired variance of manufacture, and to set the mean at the proper value.

Establishment of a satisfactory agreement with the consumer may be a matter of more difficulty. The consumer usually makes value judgments in terms of maximum error, rather than root-mean-square error, and in the general case there is no fixed or necessary connection between the two. Aside from various verbal efforts to educate consumers concerning the necessity of thinking in terms of root-mean-square errors, the only constructive work in this field known to the authors is that by Raggazzini and Zadeh[6] who have shown that, in a large number of practical cases, minimization of the largest error or minimization of the root-mean-square error lead to the same design criteria.

**Summary:** The assignment of tolerances in a complex open kinematic chain is a special example of the "search" problem, for which an explicit general solution has been found. This solution can be expressed as a very simple rule: Adjust the mean square errors so that a given amount of effort applied to reducing the mean square error of a dimension will lead to the same improvement in performance, regardless of the dimension chosen.

The interpretation of this error assignment to the customer on the one hand, and to the shop on the other hand, requires a thorough understanding of the relationships between the discordant measures used by these groups, and often a small educational campaign.

Although the whole process described in this article is rarely carried out numerically, thinking within the logical framework set forth has been proved to be profitable in difficult but typical design problems.

**Example:** As an example of the methods given symbolically, consider the rather simple linkage known as the Scott-Russell sine motion, *Fig. 7*. The input is the angle $\theta$, the output is the distance $a$. The linear dimensions affecting the accuracy of the output (which should be sin $\theta$) are $c$, $e$, $f$, $g$, $k$, $l$, $\eta$, $r$. In addition, the random variations of the slides from their nominal straight lines (roughness) I and II, and "slop" in bearings $D$, $E$, $F$, $G$, and $H$, will contribute to the error in $a$.

The trigonometric equations connecting $a$ with the linear dimensions are

$$a + e\cos\beta = f\cos\alpha + r\sin\theta + n \quad \ldots\ldots (8)$$

$$c + e\sin\beta = k + g\sin\alpha \quad \ldots\ldots (9)$$

$$l + r\cos\theta = (f + g)\sin\alpha + c \quad \ldots\ldots (10)$$

From Equation 8

$$da - e\sin\beta\, d\beta + \cos\beta\, de = -f\sin\alpha\, d\alpha + \cos\beta\, df + \sin\theta\, dr + dn \quad \ldots\ldots (11)$$

Taking similarly the total differentials of Equations 9 and 10, solve the latter for $d\alpha$, substitute in the former to find $d\beta$, and substitute both these into Equation 11 above. Simplify the result by recognizing that, while $d\alpha$ and $d\beta$ are greatly different, $\alpha \approx \beta$ in a reasonably accurate computer. Also, $e = f = g$, and $c = k$.

$$da = \frac{\partial a}{\partial c}dc + \frac{\partial a}{\partial e}de + \frac{\partial a}{\partial f}df + \ldots + \frac{\partial a}{\partial r}dr \quad (12)$$

The several partial differentials are

$$\frac{\partial a}{\partial c} = -\tan\alpha \qquad \frac{\partial a}{\partial k} = \tan\alpha$$

$$\frac{\partial a}{\partial e} = -\tan\alpha\sin\alpha - \cos\alpha \qquad \frac{\partial a}{\partial l} = 0$$

$$\frac{\partial a}{\partial f} = \cos\alpha \qquad \frac{\partial a}{\partial n} = 1$$

$$\frac{\partial a}{\partial g} = \tan\alpha\sin\alpha \qquad \frac{\partial a}{\partial r} = \sin\theta$$

And, by inspection:

$$\frac{\partial a}{\partial I} = \frac{\partial a}{\partial c}$$

$$\frac{\partial a}{\partial II} = \frac{\partial a}{\partial k}$$

"Slop" in a bearing will be equivalent to a change in one or more of the several linear dimensions terminating on the center of rotation of the bearing, according to the direction in which the motion takes place. In order to provide an estimate which is certainly not too small, one should choose for the partial differential coefficient associated with slop in a bearing, the largest of the coefficients associated with the various linear dimensions terminating at the bearing. This leads to:

$$\frac{\partial a}{\partial D} = \frac{\partial a}{\partial f} \qquad \frac{\partial a}{G} = \frac{\partial a}{\partial e}$$

$$\frac{\partial a}{\partial E} = \frac{\partial a}{\partial D} = \frac{\partial a}{\partial f} \qquad \frac{\partial a}{\partial H} = \frac{\partial a}{\partial g}$$

$$\frac{\partial a}{\partial F} = \frac{\partial a}{\partial e}$$

To simplify the illustration, assume that the input range $-90$ deg $\leqq \theta \leqq +90$ deg is used with uniform frequency, so that the weighting factor (if one wishes to consider it) would be unity everywhere. By computing the partial differential factors $\partial a/\partial c$, etc., at the seven points $\theta = 0, \pm 30, \pm 60$, and $\pm 90$ (all in degrees), Weddle's rule[7] can be used to obtain a very accurate average value for each of these coefficients. Take, for example, the coefficient $\partial a/\partial k = +\tan\alpha$. TABLE 1 shows the input angle $\theta$, the angle $\alpha$, $\partial a/\partial k = +\tan\alpha$, $(\partial a/\partial k)^2$, the weighting factors $W$ for Weddle's rule, and the products $W(\partial a/\partial k)^2$. The mean value $D_k$, given at the bottom, is arrived at by dividing the sum of the weighted coefficients by the sum of the weights.

Similar calculations for the other linear dimensions provide the list of $D$'s given in TABLE 2.

Since all the linear dimensions in the Scott-Russell

Fig. 7—Diagram of Scott-Russell sine linkage

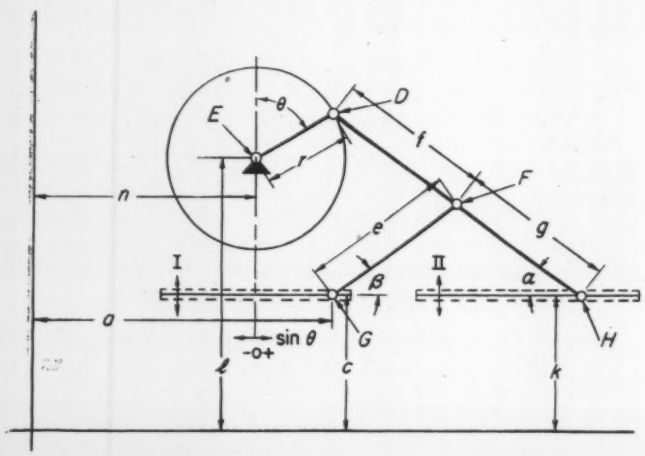
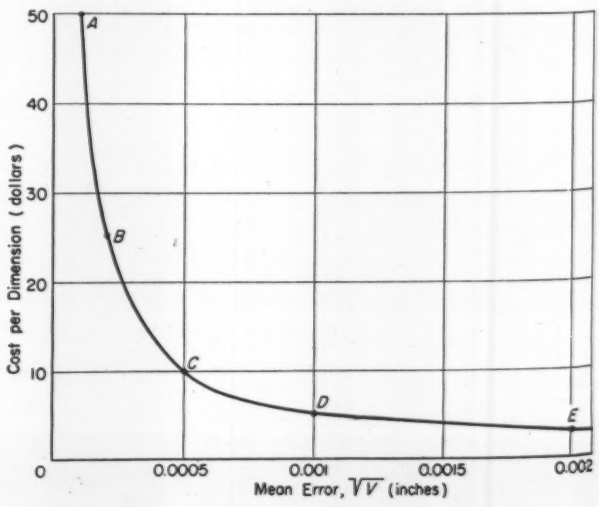



Fig. 8—Illustrative cost curve for dimensional errors



linkage would be determined by essentially the same type of machining operation, one may simplify the illustration, again, by assuming that the cost curves relating mean square error to manufacturing cost are the same for all dimensions. In an actual case, of course, it might be necessary to prepare and use a different cost curve for the dimension $c$, which is controlled by pinning the slide to the base plate, and for $r$, $e$, $f$, and $g$, which are controlled by jig-borer settings.

In the ideal case, this cost curve is a continuous curve, like that shown in *Fig.* 8. In actual shop practice, however, nothing is gained by specifying a root-mean-square error around the nominal value equal to 0.00137 inches, for example. The errors chosen would represent, effectively, the available choices of manufacturing methods; the cost curves would become a series of four or five points, like the points $A$, $B$, $C$ marked on the curve in *Fig.* 8. Here the point $E$ might represent fabrication by jig boring in the tool room, while $B$ would correspond to fabrication on a milling machine. The costs are purely illustrative, and have deliberately been distorted to avoid the controversial field of fabricating costs.

Before this cost curve is applied to the question of error assignment, the error values should be converted to mean-square-errors or variances. For this purpose, the mil² (mil-squared) is a convenient unit; one mil² is one millionth of an inch-squared. In this measure. the cost points to *Fig.* 8 can be listed in TABLE 3.

If the specification of the $j$-th dimension is changed from $B$ to $C$, for instance, the output variance will be reduced by an amount $D_j(1.0 - 0.25) = 0.75D_j$ mil², at an additional cost of five dollars. The cost of variance is $5/0.75D_j$ dollars per mil². It is this quantity which is to be equalized over the several dimensions of the sine linkage.

To illustrate this process, one may calculate the cost of variance for all the dimensions in the linkage, and for each of the four steps on the cost curve, as shown in TABLE 4.

To find the error assignments for a chosen point $Q$ = 30 dollars per mil², for example, one would choose in each the number nearest to 30. These are the boldface numbers in TABLE 4. The error specifications would be those shown in TABLE 5, the upper ends of the chosen steps, and the averaged or realized value of $Q$ would be 25.32 dollars per mil². This same value of $Q$ would be realized until the chosen value of $Q$ was increased above 36.60 dollars per mil², at which point the specification for dimension $n$ would be changed from $C$ to $B$. This stepwise increase in the realized value of $Q$ is a natural result of the discontinuous range of choices for the variance.

Tables similar to TABLE 5 would be prepared for dimensions I and II, the roughness of the slides, from the cost curves appropriate to the operations of manufacturing slides.

Slop or play in bearings is much more difficult to handle statistically than dimensional variations. The direction of the error arising from play in a bearing will change with the direction in which the structure last moved, and the chance that all the bearing slop errors will add up in the same direction is much greater than the corresponding chance that all dimensional errors would add with the same sign in the output.

**Table 1—Weighted Coefficient Determination**

| $\theta$(deg) | $\alpha$(deg) | $\partial a/\partial k$ | $(\partial a/\partial k)^2$ | $W$ | $(\partial a/\partial k)^2 W$ |
|---|---|---|---|---|---|
| 0 | 45 | 1.00 | 1.00 | 6 | 6.00 |
| ±30 | 30 | 0.58 | 0.34 | 1 + 1 | 0.68 |
| ±60 | 20 | 0.36 | 0.13 | 5 + 5 | 1.30 |
| ±90 | 15 | −0.27 | 0.07 | 1 + 1 | 0.14 |
| | | | | $D_k = 8.12/20 = 0.41$ | |

**Table 2—Weighted Coefficients**

| | | | |
|---|---|---|---|
| $D_c = 0.41$ | $D_e = 1.41$ | $D_f = 0.76$ | $D_g = 0.16$ |
| $D_k = 0.41$ | $D_l = 0.00$ | $D_n = 1.00$ | $D_r = 0.24$ |

**Table 3—Variance Versus Cost**

| Point | $A$ | $B$ | $C$ | $D$ | $E$ |
|---|---|---|---|---|---|
| Variance (mil²) ..... | 4.0 | 1.0 | 0.25 | 0.04 | 0.01 |
| Cost (dollars) ..... | 3 | 5 | 10 | 25 | 50 |

**Table 4—Cost of Output Variance Q**

(dollars per mil²)

| Dimensions | Step $D$ | $E$ to $D$ | $D$ to $C$ | $C$ to $B$ | $B$ to $A$ |
|---|---|---|---|---|---|
| $c, k$ | 0.41 | 1.62 | **16.25** | 174 | 2015 |
| $e$ | 1.41 | 0.47 | 4.70 | **50.70** | 591 |
| $f$ | 0.76 | 0.88 | **8.80** | 94.10 | 1095 |
| $g$ | 0.16 | 4.17 | **41.70** | 447 | 5210 |
| $l$ | 0.00 | ∞ | ∞ | ∞ | ∞ |
| $n$ | 1.00 | 0.67 | **6.70** | 71.50 | 833 |
| $r$ | 0.24 | 2.78 | **27.80** | 298 | 3470 |

**Table 5—Error Specifications**

for $Q$ = 30 dollars per mil²

| Dimension | $c$ | $e$ | $f$ | $g$ | $k$ | $l$ | $n$ | $r$ |
|---|---|---|---|---|---|---|---|---|
| Specification | $C$ | $B$ | $C$ | $C$ | $C$ | $E$* | $C$ | $C$ |

*Since the dimension $l$ does not affect the output, its error specification will be the lowest possible in the practice of the given shop.

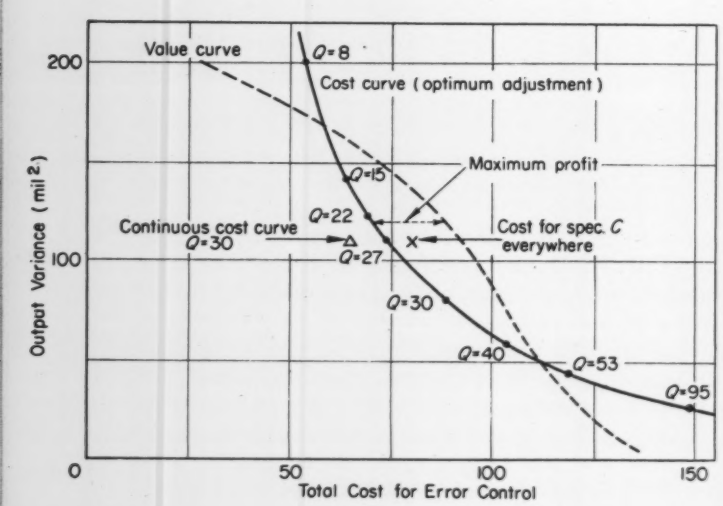
On the other hand, the past history of the mechanism will usually be such that at least a few of the bearings will be displaced in such a direction that their resulting output errors are either very small, or are opposite in sign to the majority. A complete discussion of the effect of bearing errors is much too lengthy for a general article such as this. Each mechanism containing bearings must be considered as a special case at the present time, although in many cases it is permissible to sum the effects of each bearing directly (rather than as the sum of squares), divide by two or three, and square to get an equivalent variance.

Neglecting the effect of bearing play to simplify the example, and omitting the roughness errors I and II for the same reason, one can compute from TABLE 4 an optimum curve for output variance as a function of the total cost for error control. This curve is shown in *Fig.* 9. The point resulting from assigning all seven dimensions specification $C$ is also drawn on *Fig.* 9. The distance from the optimum curve across to this point is the realizable profit from adjusting the error specifications, for that particular value of $Q$.

An assumed value curve, representing the value of a linkage as a function of its output variance, has been drawn dotted in *Fig.* 9. The profit inherent in manufacturing the linkage is the distance across from the optimum cost curve to the value curve. In this case, the profit is a maximum when the overall output variance is 1.22 mils$^2$, and one should spend a total of 68 dollars per unit on error control.

If circumstances had permitted choice from a continuous range of error specifications, the resulting profit from the use of the optimum assignment of error would have been much larger, as shown in *Fig.* 9. In large scale manufacturing, this effect may justify the provision of more different error specifications than ordinarily are available in present manufacturing or model shop operations.

Fig. 9—Illustrative adjustment chart for dimensional errors




These same considerations apply to the assembly of electrical circuits such as filters from components of varying characteristics. In this case, however, many of the individual errors are vector in character, and their composition into an output error is more complicated. R. C. Hoyt[8] has prepared very extensive tables and formulas, however, which reduce the necessary labor.

**Acknowledgment:** This work was supported in large part by the United States Air Force, under Contracts No. W-33 (038) ac 20692 and No. AF-33 (038) 22632.

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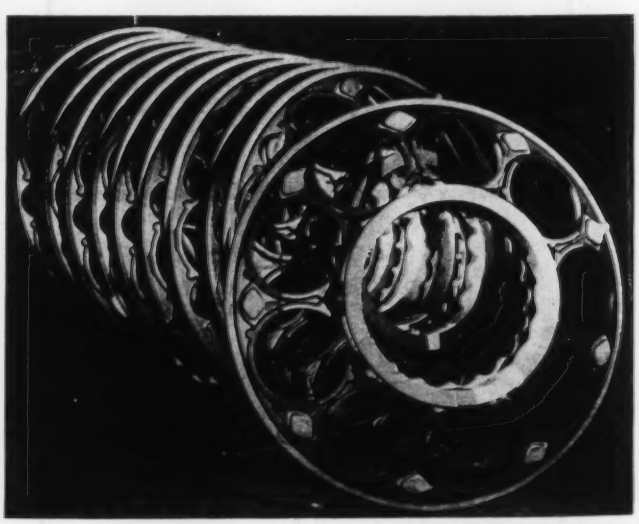
## Complex Ductile Iron Castings

ONE of the most intricate ductile iron castings produced in quantity up to the present time is a jet engine burner support casting used in the J-48 Turbo-Wasp, and produced by Howard Foundry Co. The casting is an intricate ring measuring 37¼ inches in diameter. Sections of this ring vary from ⅜-inch to 2 inches thick in the as-cast state.

In spite of the intricacy of the ductile-iron jet-engine burner support ring castings, rejections have averaged less than two per cent out of more than 500 castings shipped. The foundry also states that total scrap percentage, for all causes, compares favorably with the overall foundry scrap percentage on jobbing and semiproduction castings.



# ESSENTIALS OF A VALID PATENT

***To justify protection under the law, an invention must have four essential qualifications — authorship, ownership, novelty and utility. Lacking anyone of these, a patent may be invalid***

By Albert Woodruff Gray
*Jackson Heights, L. I.*
*New York*

IN A DECISION of the United States Supreme Court rendered a few months ago Justice Douglas had this to say of the essential features of patents, "Article I, Section 8 (of the United States Constitution) contains a grant to the Congress of the power to permit patents to be issued. But unlike most of the specific powers which Congress is given, that grant is qualified. The Congress does not have free reign, for example, to decide that patents should be easily or freely given. The Congress acts under the restraint imposed by the statement of purpose in Art. I, Sec. 8. The purpose is 'To promote the Progress of Science and useful Arts.' The means of achievement of that end is the grant for a limited time to inventors of the exclusive right to their inventions.

"Every patent is the grant of a privilege of exacting tolls from the public. The framers plainly did not want those monopolies freely granted. The invention to justify a patent, had to serve the ends of science—to push back the frontiers of chemistry, physics, and the like; to make a distinctive contribution to scientific knowledge. That is why through the years the opinions of the Court commonly have taken 'inventive genius' as the test. It is not enough that the article is new and useful. The Constitution never sanctioned the patenting of gadgets. Patents serve a higher end —the advancement of science. An invention need not be as startling as an atomic bomb to be patentable. But it has to be of such quality and distinction that masters of the scientific field in which it falls will recognize it as an advance."

*"... Congress does not have free reign ... to decide that patents should be easily or freely given."*

**Recent Changes:** In part, the provisions of the statute from which the features necessary to the validity of a patent are derived were, "Any person who has invented or discovered any new and useful art, machine, manufacture, or composition of matter, or any new and useful improvement thereof not known or used by others in this country, before his invention or discovery thereof, and not patented or described in any printed publication in this or any foreign country, before his invention or discovery thereof, or more than one year prior to his application, and not in public use or on sale in this country for more than one year prior to the application, unless the same is proved to have been abandoned, may obtain a patent therefor."

*"Every patent is the grant of a privilege of exacting tolls from the public."*

This Federal Patent Statute was amended in July, 1952, and these provisions were left essentially unchanged except for the substitution in the new statute of the word "process" for "art" in the former law:

"Whoever invents or discovers any new and useful *process,* machine, manufacture, or composition of matter, or any new and useful improvement thereof, may obtain a patent therefor."*

**Essential Factors:** An appeal in a patent infringement action came before the Federal Circuit Court of Appeals several years ago, bringing for review a decision of the District Court holding the patent of a method for removing the rough edges and burrs from expanded metal fabric a valid patent which had been infringed.

The Supreme Court of the United States has described this product as, "Expanded metal may be generally described as metal openwork, held together by uncut portions of the metal and constructed by making cuts and slashes in metal and then opening them so as to form a series of meshes or lattice work. It may be likened to the familiar woven wire openwork construction except that the metal is held together by uncut portions thereof, uniting the strands, and the whole forms a solid piece."

The controversy here centered on whether a brushing process for removing the sharp edges of metal sheets of this character was a discovery entitled to protection under the patent law or merely an improvement on a patent for producing expanded metal under an earlier patent.

The appellate court in its decision made the comment that there was no inventive thought in the mere conception of brushing expanded metal in the light of the teachings of this earlier patent of which the Supreme Court had made this definition of expanded metal, adding, "Nor is there anything of invention to be perceived in the discovery that the desired result would be obtained by brushing it in one way rather than another. Having the thought of removing the sharp edges by brushing, it would be a perfectly obvious thing to experiment in each of several directions. Indeed, failure to do this would characterize as dull even an otherwise highly skilled artisan." This the court supplemented with the comment, "Though it be elementary to do so at this late date in the development of the patent law, it is necessary to recall that three elements are necessary to validity, to wit; novelty, utility and invention."

*Editor's Note: Some of the more optimistic interpreters of the new law have found cause to disagree with this viewpoint contending that the new provisions will have a significant effect on the scope of the basic feature of invention. However, to date, their opinion is more prophetic than fact since there has been little opportunity for the courts to adopt a concerted stand either way. For complete details on this controversial view watch for "What You Should Know About the New Patent Law," an article which will appear in MACHINE DESIGN for October.

***" . . . three elements are necessary to validity . . . novelty, utility and invention."***

A few years later in another case this same court again emphasized these factors that must occur in every valid claim for patent protection. The patent in this instance, claimed by its owner to be infringed, was for a compression baling press for reducing bulky items of steel scrap such as fenders and other parts of automobile bodies, into a compact and uniformly shaped bale. The patent description was, "The combination of an open-box press provided with an offset recess in one of its walls and alined with the adjacent wall, a moveable cover for closing the filling opening, a ram working transversely of said box for initially compressing the material therein and forming a continuation of one of the walls of said recess, a second ram working longitudinally of said box for compressing material into said recess, and a third ram operable in said recess for obtaining final compression of material therein."

The description of the baling press claimed in this action to be an infringement provided that the first compression was longitudinal, the second transverse and the third vertical. The Federal District Court said of the terms used in these descriptions, "Plaintiff contends however that the terms 'transverse' and 'longitudinal' as used in its patent, are merely relative terms in defining the action of the primary and secondary rams, the movements of which are transverse to each other: in other words, that 'longitudinal' does not necessarily mean longitudinal in the ordinary sense. This theory of relativity is as difficult for me to comprehend as the one expounded by Einstein."

Nevertheless the court held this second patent valid and the Federal Circuit Court of Appeals in sustaining that decision said of these essentials of a patent, "Generally speaking, with reference to the subject matter permitted to be patented, there are four ultimate facts which must exist before an invention is patentable—authorship, ownership, novelty, not as a result of mere mechanical skill, and utility; if one is lacking it is not patentable."

***" . . . has to be of such quality and distinction that masters of the scientific field in which it falls will recognize it as an advance."***

***"Patentable novelty is sometimes found in discovering what is the difficulty with an existing structure and what change in its elements will correct the difficulty . . . "***

*"The term 'useful' . . . means that the machine will accomplish the purpose practically when applied in industry."*

**Invention:** An application for a patent for an improvement in the manufacture of multilayer cylinders for high-pressure vessels was denied by the United States Court of Customs and Appeals. The method for which this patent was sought was the application of a layer of sheet metal to a partially fabricated wall structure of a cylinder, by tightly wrapping the layer on the structure with the side edges of the layer making a longitudinal seam to be welded. A similar patent had been previously granted for applying heavy pressure by the jaws of a press to a covering of this character for a hollow shaft and then welding the edges. As the court pointed out, the patent denied was lacking invention, one of the essential three factors demanded by the patent law.

In contrast to this incident was a patent infringement action that came before a Federal Court in Wisconsin, involving the validity of a patent for a safety shield for use in the operation of power grinding wheels. In reference to this patent the court said, "The solution of the problem of grinding protection required the use of a transparent panel to permit an operator to have a clear vision of his work while screening him from the dust and metal particles thrown off by the grinding wheel, plus properly arranged illumination to avoid reflections or shadows from the wheel or work, so that the hands of the worker could effectively be protected from the wheel, permitting him to grind accurately, without the possibility of injuries and in a comfortable nonfatiguing position." Then the court added, of the solution of the problem by this inventor, "The inventor solved the problem by not merely placing two lights where there had been but one before, but by designing a small shield structure which could be mounted close to the work where it did not interfere with the accurate close grinding from a comfortable position, which protected the worker against eye and face injuries, and which provided adequate diffused illumination in an unusual manner without reflections and without shadows from parts of the machine or the work or the worker."

*"The combination . . . must produce a different force or effect, or result in the combined forces or processes, from that given by their separate parts."*

**Novelty:** The feature of novelty necessary for the protection of discoveries by the patent law from exploitation by others was highlighted in an action brought for infringement of patents for chromium plating issued in 1926. A silver manufacturer of Meriden, Connecticut contracted for the installation of a chromium plating outfit and, unbeknown to that company and without the consent of the patentee, the contractor had installed equipment for the use of this patented chromium process.

The Federal Court in granting an injunction against the further use of this process in this instance, said, "The evidence adduced clearly establishes the fact that notwithstanding all the experiments which have been made by many highly trained scientists through a period of nearly a century, no satisfactory commercial process of chromium plating was found prior to the discovery by the patentee. Today chromium plating seems commonplace." To this the court added, "This inventor discovered a latent difficulty and he located that difficulty only after repeated experiments and failures. When the difficulty had been definitely determined and located, he then had to hunt for the remedy. After continual experimenting he finally found the remedy and he is therefore entitled to the fruits of his labors.

"Patentable novelty is sometimes found in discovering what is the difficulty with an existing structure and what change in its elements will correct the difficulty, even though the means for introducing that element into the combination are old and their adaptation for the purpose involves no patentable novelty. The inventor first discovered the root of the difficulty and then discovered the remedy."

**Utility:** The third feature of patent qualifications, utility, was featured in an action involving a metallic core for concrete culverts in which the effort of the patentee to restrain the infringement of his patent ended in an adjudication of the invalidity of the patent itself. The patent assumed to provide for the production of cores so constructed that they would expand or contract, thus being adapted to culverts of different sizes. Six of these cores had been made at the time of the suit and had proved failures in every instance.

"In other words," said the federal appellate court, "the plaintiff's invention is 'new' but it is not useful. The term 'useful' as contained in the patent law when applied to a machine means that the machine will accomplish the purpose practically when applied in industry. It is to be given a practical and not a speculative meaning. It means that the machine will work and accomplish the purpose set forth in the specifications.

"Even if the machine can be made to accomplish the purpose specified, it is not useful, within the meaning of the patent law, if from its inherent nature

it will accomplish the purpose only to such a restricted extent as to make its use in industry prohibitive. This has been the interpretation put upon the term in the patent law from the earliest decisions to the present time."

**Combinations:** Of combination features demanded in inventions by the patent law before the protection of this statute will be extended, and of the application of the law itself to combinations operating as inventions, the Supreme Court of the United States said in an opinion rendered many years ago, "The combination, to be patentable, must produce a different force or effect, or result in the combined forces or processes, from that given by their separate parts. There must be a new result produced by their union; if not so, it is only an aggregation of separate elements.

"An instance and an illustration are found in the discovery that by the use of sulphur mixed with india-rubber, the rubber could be vulcanized. The combination of the two produced a result or an article entirely different from that before in use. Another illustration may be found in the frame in a sawmill which advances the log regularly to meet the saw and the saw which saws the log; or in the sewing machine, where one part advances the cloth, and another forms the stitches, the action being simultaneous in carrying on a continuous sewing.

"A stem winding watch key is another instance. The office of the stem is to hold the watch or hang the chain to the watch; the office of the key is to wind it. When the stem is made the key, the joint duty of holding the chain and winding the watch is performed by the same instrument. A double effect is produced or a double duty performed by the combined result.

"In these and numerous like cases the parts co-operate in producing the final effect, sometimes simultaneously, sometimes successively. The result comes from the combined effect of the several parts, not simply from the separate action of each, and is therefore, patentable."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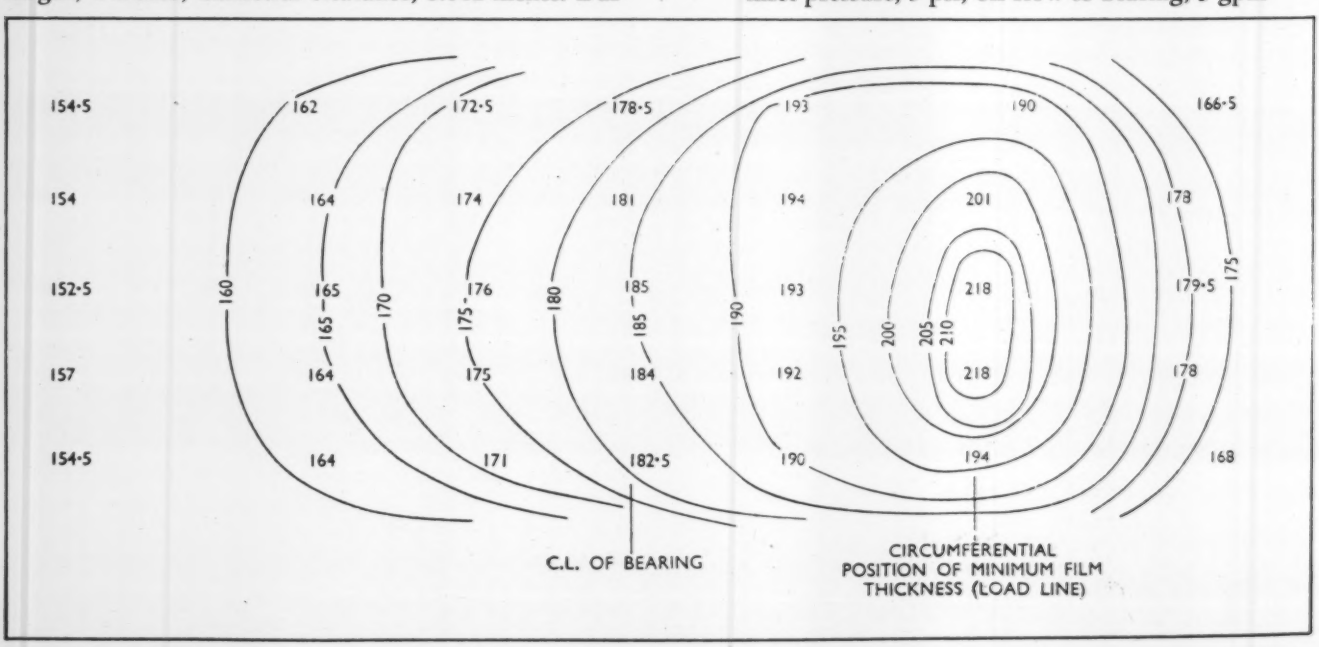
# "Weather Maps" for Bearing Design

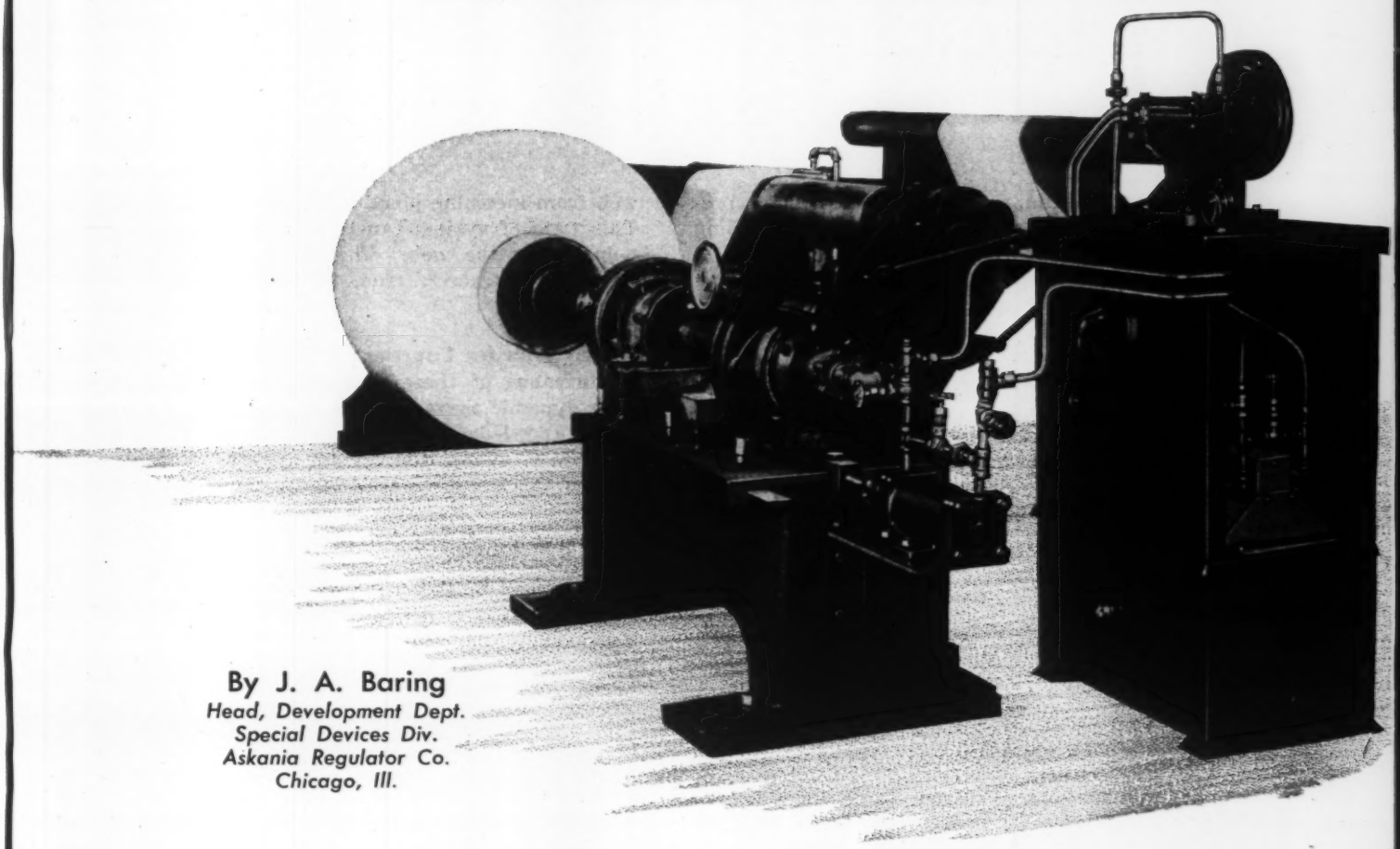
TO evaluate journal bearing performance under conditions for which no previous data existed, engineers of the Parsons and Marine Engineering Turbine Research and Development Association fitted 47 thermistors to a test bearing and plotted isothermal diagrams, *Fig.* 1, similar to weather maps, of bearing temperature. Thermistors are semiconductors having a large change in resistance due to temperature change and are stable over long periods.

Tests were performed using a 6-inch diameter journal bearing with loads to 1000 psi at speeds to 290 feet per second. Effects of viscosity, journal clearance, chambering, load and peripheral speed can all be correlated with other design data.

Fig. 1—Isotherms in a full journal bearing of Admiralty white metal on bronze. Bearing diameter, 6 inches; length, 4 inches; diametral clearance, 0.012-inches. During this test, journal speed was 185 feet per second; journal load, 500 psi; oil inlet temperature, 120 F; oil inlet pressure, 5 psi; oil flow to bearing, 3 gpm



# Control of MOVING WEBS... *analysis and comparison of dynamic behavior for three basic types of lateral control*



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SIDE-POSITION control of moving webs has long been essential to efficient production in many process applications. Since greatest economies can usually be realized at highest web speeds with larger mill rolls, control requirements have become more exacting. Greater speeds imply more severe disturbances to be corrected and result in a higher premium paid in waste material per unit time during which errors exist. Higher web speeds also affect the behavior of the control loop. An effort to improve overall performance leads to the study of the dynamics of the web itself.

**Types of Control Systems:** Web-control arrangements are of three basic types: (1) Pay-off control, (2) Wind-up control, and (3) Intermediate or pivoting-roll control.

PAY-OFF CONTROL: Illustrated in *Figs.* 1 and 2, the pay-off reel controller is typically used with laminators, slitters and printing machinery. The position of the web is usually detected by an optical or pneumatic head. The controller and actuator correct positional errors stemming from irregularities of the roll on the carriage by lateral movements of the carriage and reel assembly.

Fig. 1—Pay-off control system. Web position is measured by the sensing head, upper center. Its output is transmitted pneumatically to the controller, right, and finally to the actuating cylinder, lower center, which moves the carriage and reel assembly on its parallel ways

WIND-UP CONTROL: Material at the end of a strip process is commonly rewound onto a reel. The smooth

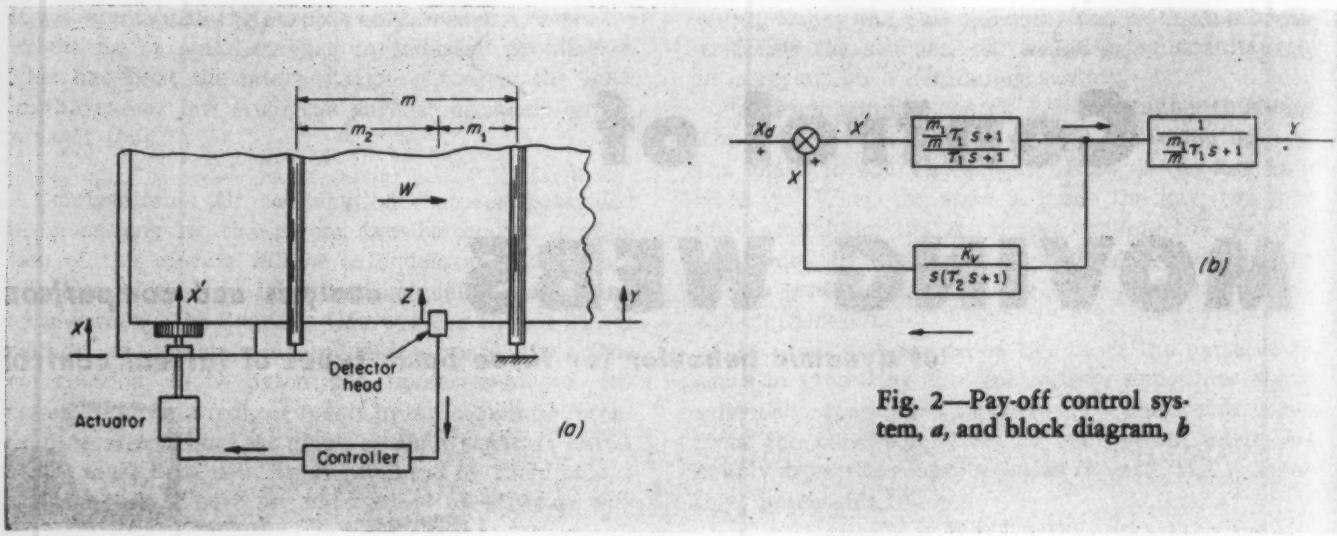



**Fig. 2—Pay-off control system, *a*, and block diagram, *b***

reel edge that results from automatic control precludes damage to protruding turns during handling or storage and aids in future process steps. *Fig.* 3 shows such a system. The position of the incoming web is sensed by the head. Errors between the carriage position and the position of the web are corrected by the controller and actuator. The contour of the finished reel depends on the web position at point of contact on the reel.

INTERMEDIATE ROLL CONTROL: Edge position control can be achieved in the absence of either reel by varying the angular position of an intermediate guide roll* as in *Fig.* 4. Moving the roll by an angle $\theta$ shifts the web from incoming position $X$ to outgoing position $Z$. This type of system can be located at any desirable point along the web. The possibility of small roll inertia is attractive from the standpoint of control performance.

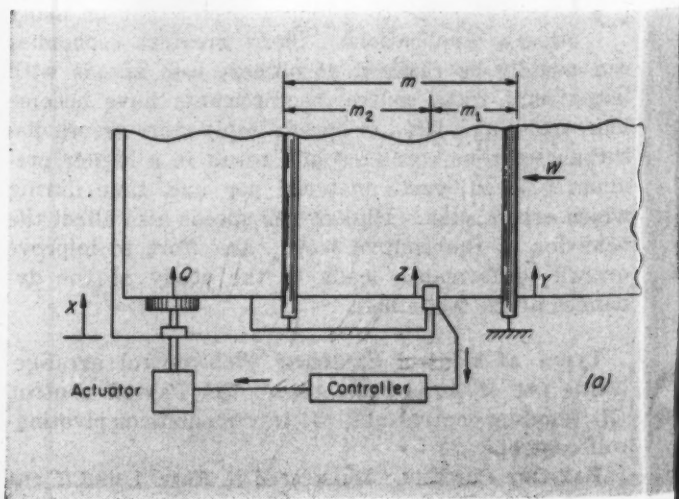
**Web Transfer Function:** Evaluation of the relative performance of these control systems requires that their dynamic characteristics be established. A requisite is knowledge of the dynamic behavior of the web itself as it affects the control system. Consider the case of the pay-off control in *Fig.* 2*a*. The way that web position $Z$ responds to changes in carriage position $X$ is a contributing factor to system stability and ultimately to any performance criterion. This response will be called the web transfer function and will be expressed in the LaPlace transform notation. This transfer function will be investigated by consideration of the lateral behavior of a web traveling between two rollers.

In *Fig.* 5*a*, a portion of a moving web is shown between any two rolls traveling to the right with velocity $W$. If a high lateral friction force is assumed between the web and roller $BD$ and if angle $\alpha$, resulting from changes in position $X$, is small, then $Y$ will be led to follow $X$ by the incoming angle $\alpha$. One may

*S. E. Amos—"Web Guiding Control," MACHINE DESIGN, Sept. 1950, Pages 159-162.

### Nomenclature

$b$ = Web width
$C$ = Constant of slipping
$d$ = Diameter of cocking roll
$e$ = Natural log base
$F$ = Force
$K$ = Open loop transfer function
$K_v$ = Zero frequency loop gain
$m$ = Roller spacing
$Q$ = Lateral web position
$R$ = Ramp function magnitude
$s$ = LaPlace operator
$t$ = Time
$T$ = Web tension
$T_f$ = Roller-web friction force
$v$ = Web position on cocking roll
$W$ = Web speed
$X, X_d, X'$ = Lateral web position
$Y$ = Lateral web position
$Z$ = Lateral web position
$\alpha$ = Web guiding angle
$\theta$ = Angle of cocking roll
$\eta$ = Coefficient of friction
$\phi$ = Web angle
$\tau$ = Time constant



solve for the transfer function $Y/X$ by expressing $Y$ as a function of $X$. The lateral velocity $dY/dt$ is proportional to the web velocity and the tangent of the angle $\alpha$. Thus,

$$\frac{dY}{dt} = W \tan \alpha \quad (1)$$

The geometry of the web and rollers gives

$$\tan \alpha = \frac{X - Y}{m} \quad (2)$$

Substituting Equation 2 into Equation 1 gives

$$\frac{dY}{dt} = \frac{W}{m}(X - Y) \quad (3)$$

Representing $d/dt$ by the LaPlace operator $s$, permits rewriting of Equation 3 as

$$sY = \frac{W}{m}(X - Y) \quad (4)$$

which can be simplified to

$$\frac{Y}{X} = \frac{1}{\tau_1 s + 1} \quad (5)$$

where

$$\tau_1 = \frac{m}{W} \quad (6)$$

If the position $X$ is suddenly shifted an amount $X_1$, then according to Equations 5 and 6, $Y$ will respond exponentially as

$$Y(t) = X_1(1 - e^{-t/(m/W)}) \quad (7)$$

Thus the web introduces an exponential or single order lag term into any control loop involving the geometry of *Fig.* 5*a*. The time constant of this lag depends on web speed and roll spacing.

The assumptions leading to this derivation cannot always be justified. The web, suddenly deformed as in *Fig.* 5*a*, will tend to have a nonuniform force distribution which will assume a trapezoidal, then triangular shape, as $X$ increases. The special case wherein points $C$ and $D$ just go slack is shown. Tension $T$ can then be considered to act through the centroid of the force triangles, producing a lateral shifting force equal to $Tb/3m$. So long as the roll friction force $T_f$ exceeds this value, lateral shifting will not occur. A lateral roll friction force,

$$T_f \geqq T\frac{b}{3m} \quad (8)$$

will then be adequate to prevent lateral sliding of the web. Larger values of $X$ can require that $T_f$ go as high as

$$T_f \geqq T\frac{b}{m} \quad (9)$$

to prevent slipping. This latter case occurs when the entire tension $T$ is trasmitted by the extreme fibers at $A$ and $B$.

The value of friction force $T_f$ available depends on the roll-to-web friction coefficient and the angle between the incoming and outgoing web planes at roll $BD$. From *Fig.* 5*b* the resultant force on the roller resulting from web tension $T$ will be

$$F = 2T \cos\frac{\phi}{2} \quad (10)$$

If $\eta$ is the friction coefficient, then

$$T_f = 2T\,\eta \cos\frac{\phi}{2} \quad (11)$$

Thus, with Equations 9 and 11 combined, slipping can never occur provided

$$2\,\eta \cos\frac{\phi}{2} \geqq \frac{b}{m} \quad (12)$$

Equation 12 is a sufficient but not a necessary condition to establish the single-order web transfer function given in Equation 5 for any given application.

Web material plays a vital part in this slipping characteristic. With webs of paper or cloth, objectionable wrinkling or web breaks will occur before

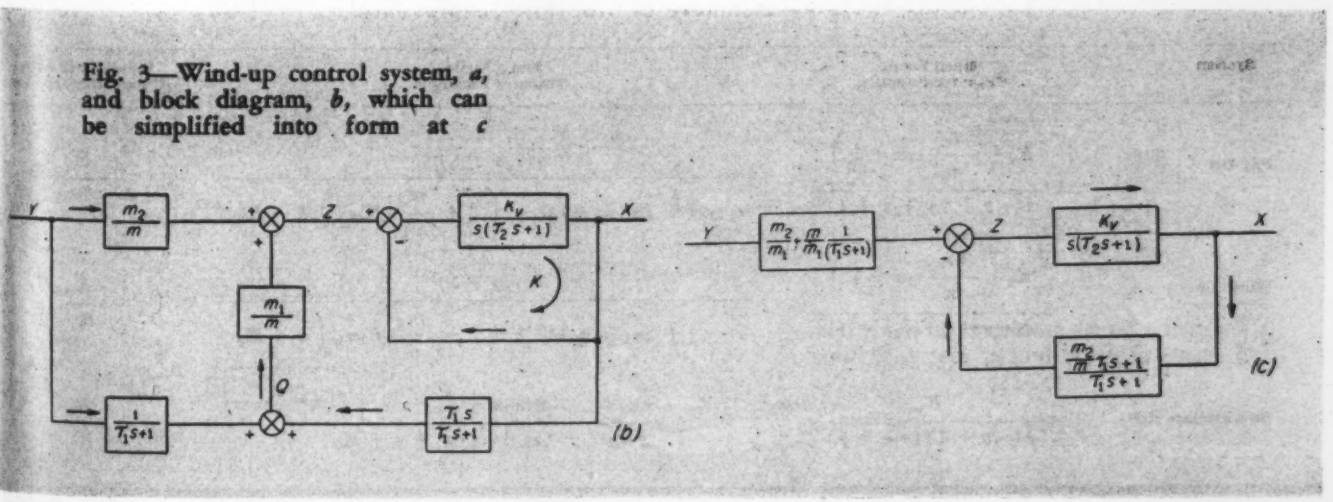



**Fig. 3—Wind-up control system, *a*, and block diagram, *b*, which can be simplified into form at *c***

the limiting value of $\alpha$ is reached. Therefore, slipping may never be encountered because of the requirement of small changes of $X$ to prevent damage. This is not necessarily true of metallic webs.

When slipping occurs on roll $BD$ of *Fig. 5a*, the approximate transfer function can be written as

$$\frac{Y}{X} = C + \frac{1 - C}{\tau_1 s + 1} \quad \ldots\ldots (13)$$

where $C$ is a constant equal to or less than 1. Rewriting Equation 13 gives

$$\frac{Y}{X} = \frac{C\tau_1 s + 1}{\tau_1 s + 1} \quad \ldots\ldots (14)$$

Equation 13 assumes an instantaneous slippage of $C$ times the change in roll position followed by exponential guiding action. In the extreme when $C = 1$ no dynamic web effects exist. When $C = 0$ the pure exponential response of Equation 5 exists. In specific controllers that will be discussed, it will be assumed that no slipping occurs and thus that Equation 5 applies.

Now that the behavior of an independent section of web has been examined, consideration of an entire control system is possible. Effects of head location, web speed, loop gain and roller spacing will be considered for the three types of systems previously described.

**Pay-Off Control:** The pay-off control loop consists of the controller, actuator, and web, as in *Fig. 2*. It will be assumed that the controller and actuator can be represented by the function,

$$\frac{X}{Z} = \frac{K_v}{s(\tau_2 s + 1)} \quad \ldots\ldots (15)$$

This relationship presupposes an integral type controller having an inherent time lag of its own equal to $\tau_2$, and a gain $K_v$. If a unit error in $Z$ were applied to the controller, the output $X$ would, in the steady state, change at rate equal to $K_v$ units per second. This function can be altered to fit whatever controller is to be used. Referring to *Fig. 2a*, the web position $Z$ depends on the two positions $X'$ and $Y$. Assuming a smooth roll, then $X = X'$ and

$$Z = \frac{m_1}{m} X + \frac{m_2}{m} Y \quad \ldots\ldots (16)$$

Substituting Equation 5 for $Y$ and rearranging give

$$\frac{Z}{X} = \frac{\frac{m_1}{m}\tau_1 s + 1}{\tau_1 s + 1} \quad \ldots\ldots (17)$$

where $\tau_1 = m/W$.

The open loop transfer function $K$ equals the product of Equations 15 and 17 or

$$K = \frac{K_v\left(\frac{m_1}{m}\tau_1 s + 1\right)}{s(\tau_1 s + 1)(\tau_2 s + 1)} \quad \ldots\ldots (18)$$

System stability is based on this equation. The web dynamic effect is similar to that of an under-compensated integral network. The location of the sensing head determines the attenuation of the network while the web speed and roller spacing determine its characteristic frequency. Locating the head at the carriage cancels the dynamic term. Locating it at or beyond the first idler roller, results in a single lag function. The efficacy of location will be discussed in a later section.

Let

$$X' = X + X_d \quad \ldots\ldots (19)$$

The performance of the system is described by the relation between the output position $Y$ and the input disturbance $X_d$, called the load-error function. Then from *Fig. 2a* and Equations 5, 15, 17 and 18 the block diagram shown in *Fig. 2a* can be constructed. This in turn leads to the load-error function:

**Table 1—Summary of Transform Expressions**

| System | Open Loop Transfer Function | Load-Error Transfer Function | Final Error with Ramp Disturbance |
|---|---|---|---|
| Pay-Off | $\dfrac{K_v\left(\frac{m_1}{m}\tau_1 s + 1\right)}{s(\tau_1 s + 1)(\tau_2 s + 1)}$ | $\dfrac{s(\tau_2 s + 1)}{\tau_1\tau_2 s^3 + (\tau_1 + \tau_2)s^2 + \left(1 + \frac{m_1}{m}K_v\tau_1\right)s + K_v}$ | $\dfrac{R}{K_v}$ |
| Wind Up | $\dfrac{K_v\left(\frac{m_2}{m}\tau_1 s + 1\right)}{s(\tau_1 s + 1)(\tau_2 s + 1)}$ | $\dfrac{s(\tau_2 s + 1)}{\tau_1\tau_2 s^3 + (\tau_1 + \tau_2)s^2 + \left(1 + \frac{m_2}{m}K_v\tau_1\right)s + K_v}$ | $\dfrac{R}{K_v}$ |
| Intermediate Roll | $\dfrac{K_v}{s(\tau_1 s + 1)(\tau_2 s + 1)}$ | $\dfrac{s(\tau_2 s + 1)}{\tau_1\tau_2 s^3 + (\tau_1 + \tau_2)s^2 + s + K_v}$ | $\dfrac{R}{K_v}$ |

$$\frac{Y}{X_d} = \frac{s(\tau_2 s + 1)}{s(\tau_2 s + 1)(\tau_1 s + 1) + K_v\left(\frac{m_1}{m} s + 1\right)} \quad (20)$$

This function may be examined for its response to a continuous disturbance by applying the LaPlace final value theorem. Thus, when $X_d$ is characterized by a unity step disturbance as might occur at a paste in the web, then $X_d = 1/s$. The final value theorem shows that when $t = \infty$, $Y = 0$; therefore, no steady error in $Y$ exists following a step change in $X_d$. If, on the other hand, $X_d$ is a ramp function, as it may be with telescoping rolls, then its transformed value $X_d = R/s^2$, and when $t = \infty$, $Y = R/K_v$. Thus, a steady error of $R/K_v$ (inches) accompanies a constant run-out rate of $R$ (inches per second). Since the ramp function is typical of the disturbance conditions found in practice, loop gain $K_v$ should be made as large as possible consistent with stability.

**Wind-Up Control:** In the case of a wind-up controller, the sensing head is fixed to the wind-up carriage as in *Fig.* 3*a*. If it is assumed that carriage motion does not affect incoming web position $Y$, then three equations are required to describe the system. First the web position at the head, $Z$, depends on $Y$ and $Q$ as, by superposition,

$$Z = \frac{m_1}{m} Q + \frac{m_2}{m} Y \quad (21)$$

Second, assuming the same controller characteristic as Equation 15, then

$$X = \frac{K_v}{s(\tau_2 s + 1)} (Z - X) \quad (22)$$

Third, the instantaneous position $Q$ depends on $X$ and $Y$ as

$$Q = \frac{\tau_1 s}{\tau_1 s + 1} X + \frac{1}{\tau_1 s + 1} Y \quad (23)$$

where $\tau_1 = m/W$.

*Fig.* 3*b* is the block diagram which represents these equations. Stability problems are centered in the righthand loop containing the servo integration.

Shifting summing points and multiplying blocks give the combined block diagram of *Fig.* 3*c* which can be drawn to replace *Fig.* 3*b*. Multiplying the functions in the two loop blocks gives for the open-loop transfer function:

$$K = \frac{K_v\left(\frac{m_2}{m}\tau_1 s + 1\right)}{s(\tau_1 s + 1)(\tau_2 s + 1)} \quad (24)$$

Notice that this is identical in form to Equation 18 for the pay-off reel.

Errors in the wind-up operation are the result of differences between the instantaneous position $Q$ and the instantaneous carriage position $X$. Thus, the load-error function equals $(Q - X)/Y$, or

$$\frac{Q - X}{Y} = \frac{ms(\tau_2 s + 1)}{m(\tau_1 s + 1)[s(\tau_2 s + 1) + K_v] - m_1 K_v \tau_1 s} \quad (25)$$

Derivation of Equation 25 is given in the appendix section.

Again application of the LaPlace final value theorem shows that for a step input to $Y$, $Q - X = 0$ in the steady state, and for a ramp type input to $Y$, as before, $Q - X = R/K_v$. Again the controller loop gain is an important figure of merit since the ramp is representative of actual disturbances in $Y$.

**Intermediate Roll Positions:** *Fig.* 4*a* shows a method of directing the web by rotating a pivoted intermediate roll. With the roll pivot axis located in the plane of the incoming web, the incoming position $X$ is unaffected by the pivot angle $\theta$. Thus, the web position on the roll at point of leaving, $v$, is independent of $\theta$. The web position relative to the frame at the point of leaving is

$$Y = v + \theta d \quad (26)$$

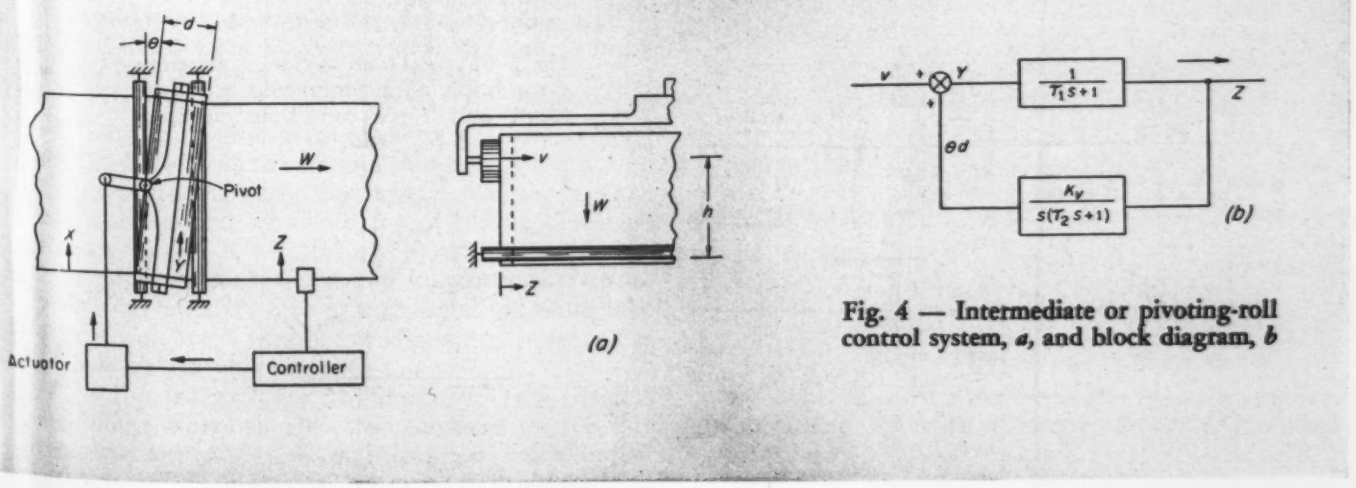



Fig. 4 — Intermediate or pivoting-roll control system, *a*, and block diagram, *b*

## CONTROL OF MOVING WEBS

Since only the translation of the web, $Y$, influences the outgoing position $Z$,

$$\frac{Z}{Y} = \frac{1}{\tau_1 s + 1} \qquad (27)$$

With the same controller function as in the other examples,

$$\frac{\theta d}{Z} = \frac{K_v}{s(\tau_2 s + 1)} \qquad (28)$$

Equations 27 and 28 lead to the block diagram of *Fig. 4b*, whose open loop function becomes

$$K = \frac{K_v}{s(\tau_2 s + 1)(\tau_1 s + 1)} \qquad (29)$$

The load error function is simply

$$\frac{Z}{v} = \frac{s(\tau_2 s + 1)}{s(\tau_2 s + 1)(\tau_1 s + 1) + K_v} \qquad (30)$$

Applying the final value theorem to $Z/v$ gives the same results as before.

**Web Dynamics Comparison:** TABLE 1 shows the tabulation of open-loop and load-error functions. Notice that the pay-off and wind-up systems are functionally identical when $m_1$ and $m_2$ are interchanged both in the transfer function and the load-error function.

In each case the web dynamic effect takes on the form of an undercompensated integral network, whose attenuation depends on head location and whose characteristic frequency depends on the web speed and roller geometry. In the pay-off case it can be seen that locating the head at the reel (*Fig. 2a*) makes $m_1 = m$. This location cancels the web dynamic terms. For most controller functions and particularly when web speed varies substantially, this location of the head is preferred. *Fig. 6* shows a method of mounting the head in this manner. The two rollers shown in the center of the picture move together with the pay-off reel assembly. Locating the sensing head between these two insures the cancellation of the web lag.

For the wind-up reel, *Fig. 3a*, the head is moved to the upstream side of the fixed reel to achieve the same result. This eliminates the need for having the idler roll move with the carriage. It is not uncommon to find systems having $m_1$ less than one which will oscillate at low web speeds where $\tau_1$ is large but will be stable at high speeds where $\tau_1$ becomes small.

If web speed is a constant, then it may be desirable to use the web dynamic effect to perform integral compensation in the loop. In so doing, the loop gain $K_v$ may be increased with a resulting reduction in run-out rate errors. The head location will then depend on the attenuation characteristic desired best to fit the controller dynamics. If, contrary to the original assumption, pure lateral slipping occurs, then web dynamics disappear whatever the location of the head.

The intermediate roll system is entirely equivalent to a pay-off system with $m_1 = 0$. Thus, the web time constant will be a part of loop dynamics at all times. Although height $h$ may be kept small compared with $m$ in the other systems, there will be situations, particularly during starting, when the web time constant will over-ride all other dynamic elements in the loop. This factor may lead to the instability condition mentioned before.

**Error Detection:** Any control system is limited in its controlling accuracy by some minimum system error which will just initiate corrective action. This minimum error is inversely related to the maximum loop gain which can be carried.

In the case of the integral type of controller it is also dependent on the part of the loop having the highest gain. Thus, high gain ahead of the integrator provides for smaller minimum accuracy, usually at the expense of lower maximum output speeds. A high permissible loop gain is obviously desirable from this standpoint as well.

**Tracking Error:** The most important type of web guiding disturbance contains only low frequencies since it is often the result of telescoped rolls being unwound or a drifting effect in process machines. In

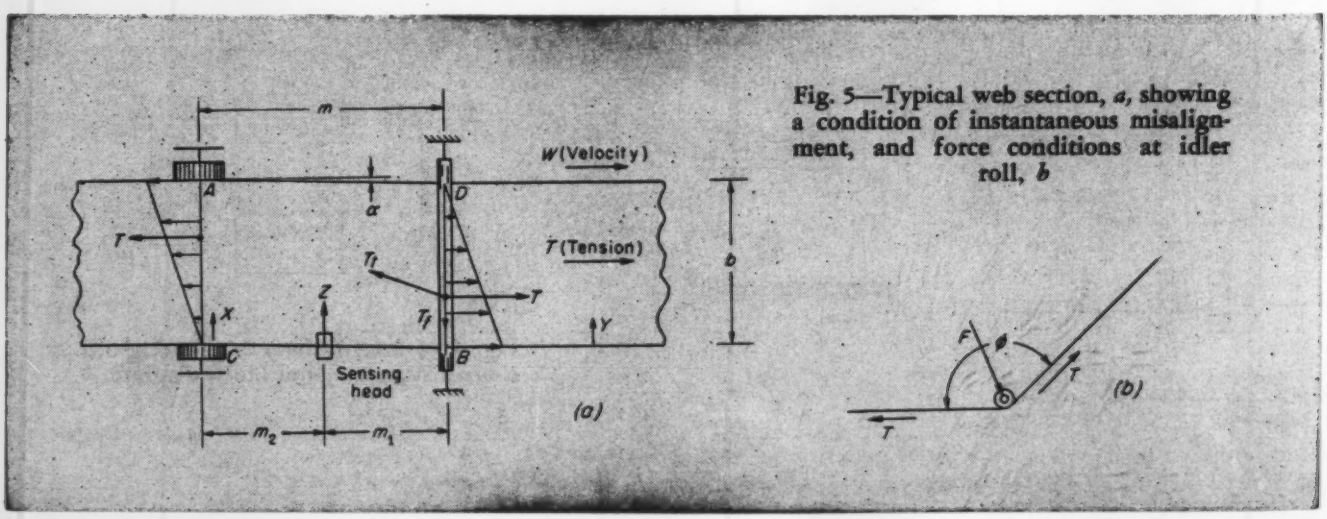



**Fig. 5—Typical web section, *a*, showing a condition of instantaneous misalignment, and force conditions at idler roll, *b***

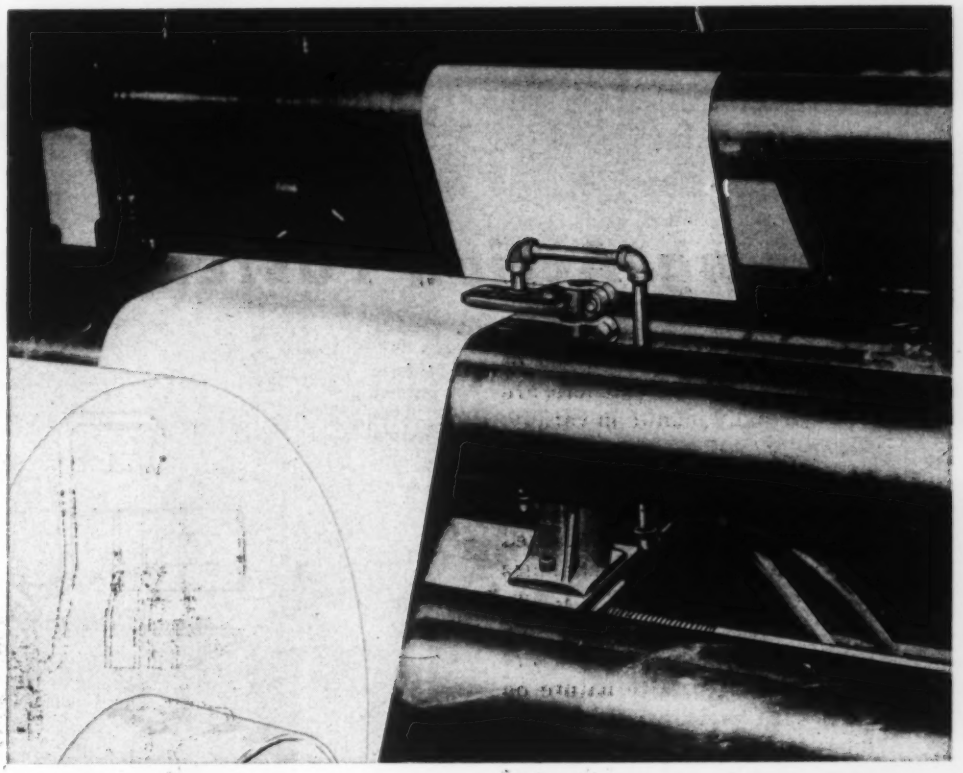


Fig. 6 — Pneumatic sensing head of pay-off control located between a double first-idler roll system

these cases a constant runout rate is a good approximation of a typical disturbance. Therefore the most significant system figure of merit is the loop gain $K_v$ since previous sections have shown that the error incurred in the presence of a constant web runout rate is inversely proportional to the loop gain.

Web disturbance may have a relatively high frequency effect when caused by a lopsided pay-off reel. The disturbing frequency then is equal to the rotational velocity of the reel. Frequencies may reach 20 or more cycles per second with fast webs and small reels. If it is desirable to correct for these disturbances, the high frequency characteristics of the control system become important. Web dynamics should then be canceled by proper head location and a control system having a wide band pass should be used. Consideration of the disturbances to be encountered will determine whether high loop gain or the controller band pass is more important.

**Summary:** Lateral shifting of a moving web is characterized by a single lag or a lag-lead function whose time constant and attenuation factors depend on web speed, roller spacing, web-to-roller friction and web tension. With a moving carriage system, proper sensing head location can eliminate this dynamic term from the control loop. The cocking roll method can minimize but not eliminate the attendant time constant.

In all three cases using and integrating-type controller, an ultimate zero system error follows a step disturbance and a steady tracking error accompanies a constant runout rate.

The frequency of the disturbance to be controlled determines where to place the emphasis on the system dynamics. Usually a high loop gain is to be preferred over high band pass since constant runout rate errors are most frequently encountered.

**Appendix:** Derivation of the load-error transfer function for the wind-up system of *Fig. 3a* is based on Equations 21, 22 and 23.

The error of the system is the difference between the web position as it is wound on the reel and the reel itself. The load changes causing such errors appear as variations of incoming web position $Y$. Thus the function $(Q-X)/Y$ must be derived. Solving Equation 22 for $Z$ and substituting into Equation 21 give

$$\frac{1}{K_v}[s(\tau_2 s + 1) + K_v]X = \frac{m_1}{m} Q + \frac{m_2}{m} Y \quad \ldots\ldots (31)$$

Substituting $Q$ of Equation 23 into Equation 31 gives an expression of $X$ in terms of $Y$ which can be reduced to

$$\frac{X}{Y} = \frac{m_1 + m_2(\tau_1 s + 1)}{\frac{m}{K_v}(\tau_1 s + 1)[s(\tau_2 s + 1) + K_v] - m_1 \tau_1 s} \quad (32)$$

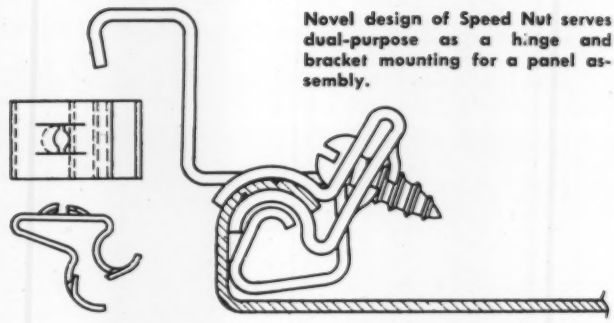
Solving Equation 23 for $X$ and substituting in Equation 31 give an expression for $Q$ in terms of $Y$ which can be reduced to

$$\frac{Q}{Y} = \frac{\frac{m}{K_v}[s(\tau_2 s + 1) + K_v] + m_2 \tau_1 s}{\frac{m}{K_v}(\tau_1 s + 1)[s(\tau_2 s + 1) + K_v] - m_1 \tau_1 s} \quad (33)$$

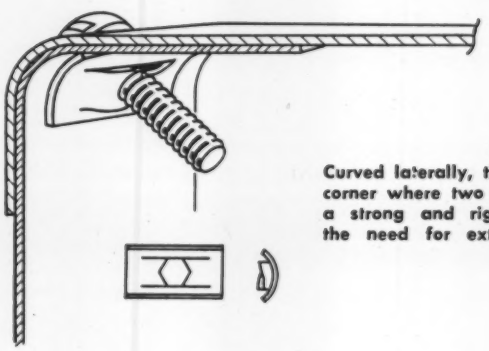
Subtracting Equation 32 from Equation 33 gives Equation 25.

# Spring-Action Fasteners

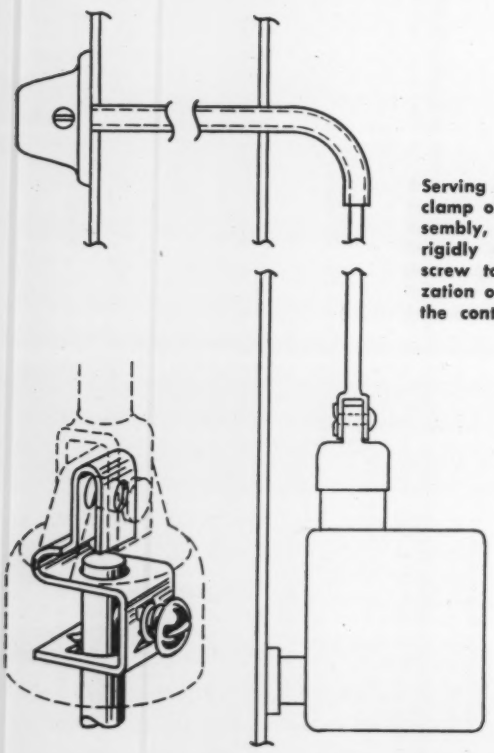
TYPES and applications of spring-action fasteners, are virtually infinite in variety. Generally selflocking and light in weight, they provide a resilient nut of moderate load capacity which can be readily adapted to rapid assembly techniques with either threaded or unthreaded studs. Although the most familiar applications are those of a decorative nature on parts such as door panels, moldings, knobs, etc., special types have extended the usefulness of these fasteners to a variety of other design requirements. The accompanying illustrations show some of the more unusual types, and applications, of Speed Nuts manufactured by Tinnerman Products Inc.



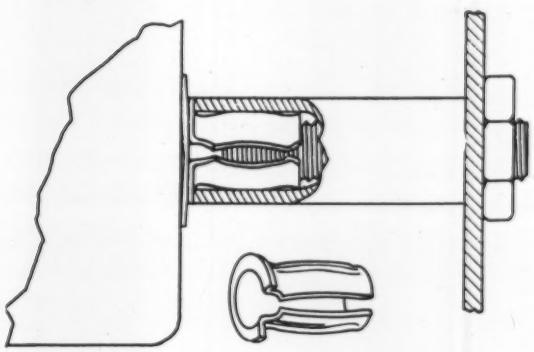
Novel design of Speed Nut serves dual-purpose as a hinge and bracket mounting for a panel assembly.



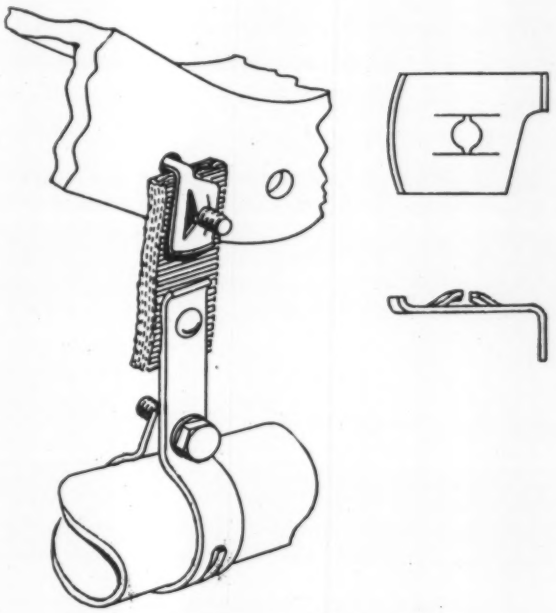
Curved laterally, this special type fits in the corner where two panels overlap, providing a strong and rigid joint and eliminating the need for extra braces and brackets.



Serving as an adjustment clamp on a control rod assembly, this fastener is rigidly mounted with a screw to permit synchronization of a knob dial with the control mechanism.

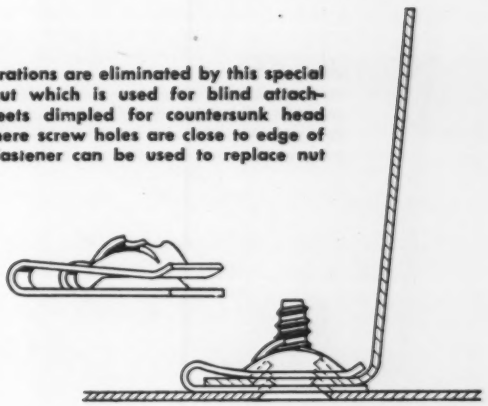


Tubular clips, in permanent lock or removable types, are advantageous for attachments where there is access to one side only. In the application shown, a special tubular type serves as a retainer to hold spacer tubes in place on mounting bolts; the barrel shape provides a resilient wedging action between the spacer and bolt.

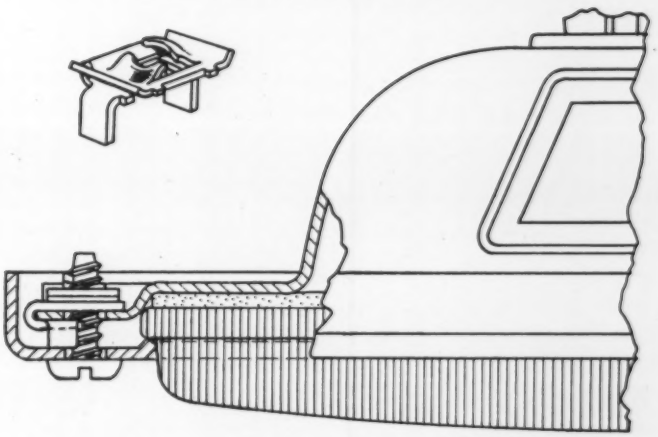


Vibration mounting for tubular members eliminates need for spanner and lock washers and distributes fastening load over large area of the fabric strap. Turned down leg engages frame and prevents turning.

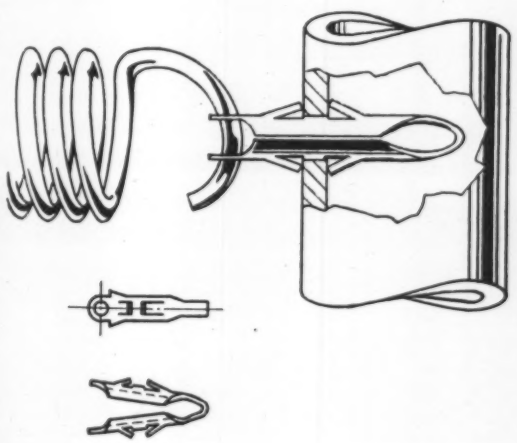
Riveting operations are eliminated by this special "U" type nut which is used for blind attachment of sheets dimpled for countersunk head screws. Where screw holes are close to edge of sheet, this fastener can be used to replace nut plates.



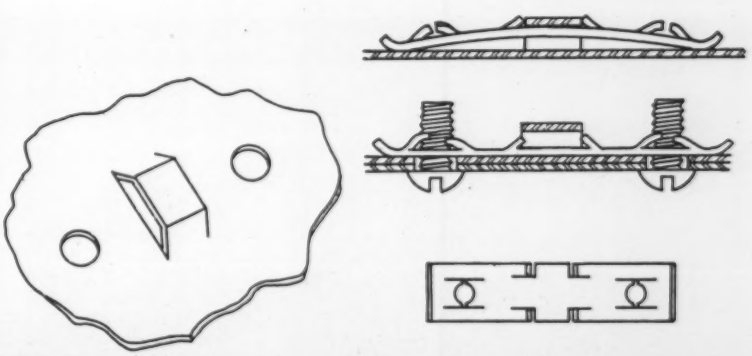
Eliminating riveted or welded cage nuts and tapped plates, this "J" type nut insures permanent fastening under vibration loads and minimizes lens breakage in units such as lamps. The tabs serve as spacers to prevent collapse of the lens retaining rings.



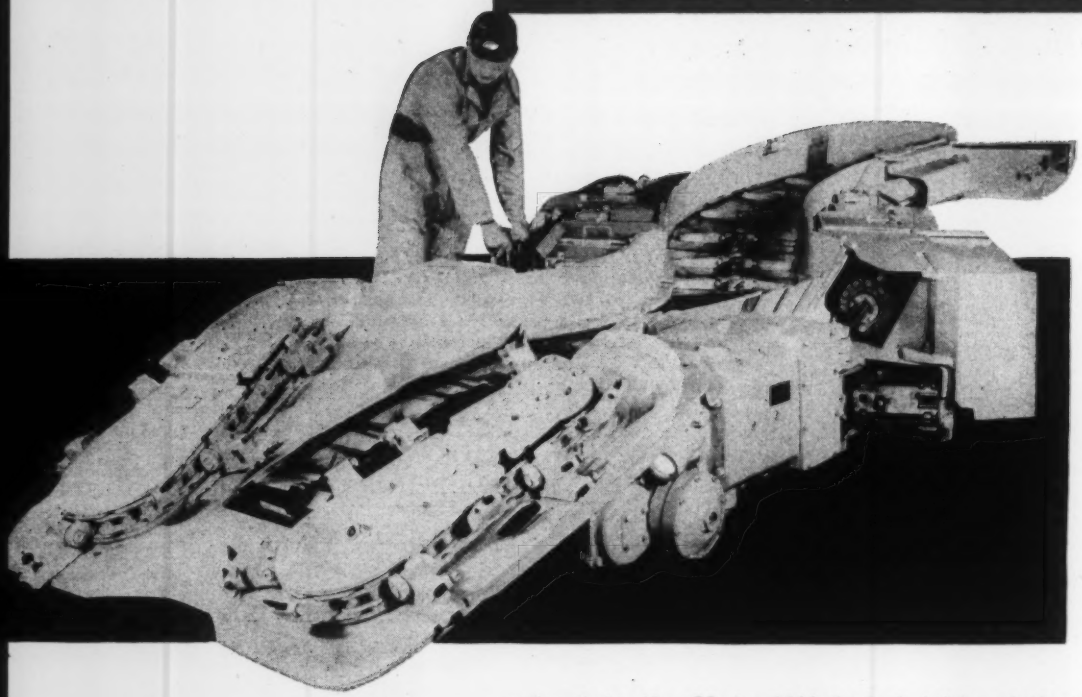
In anchoring coil springs to tubular sections, these clips eliminate the need for drilling through both walls of tube. Clips press into holes and are locked securely by sheared prongs.



Twin types are used for attaching assemblies having fastening locations in pairs. Four sheared legs keep the nut in bolt receiving position during assembly.

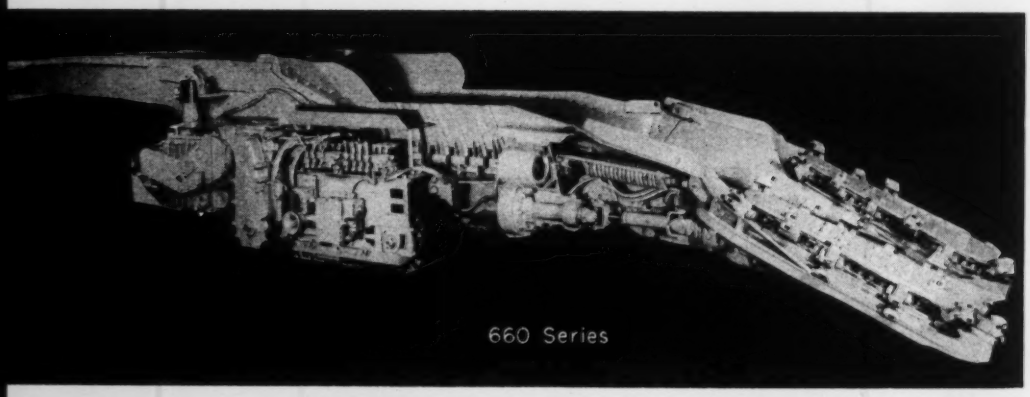


# Coal Loader R

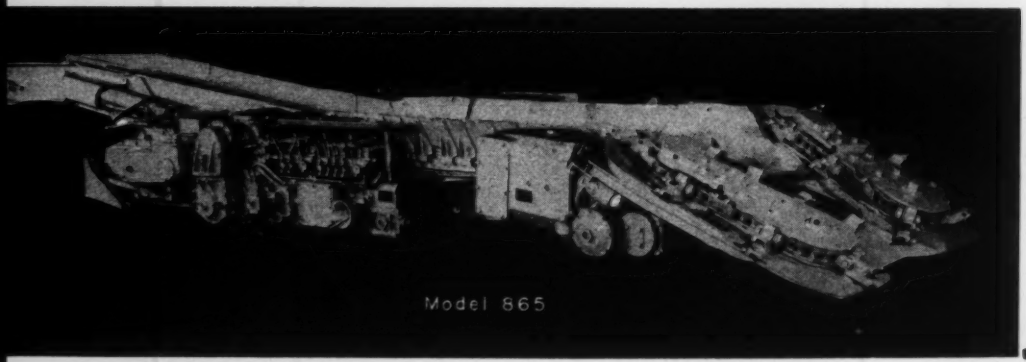


BY UTILIZING four drive motors instead of two in a newly designed model of their Swing-motion Loaders, Goodman Mfg. Co. has been able to eliminate a long, complex mechanical transmission, and has reduced overall height and total power requirements. Built for mining coal in low seams, the new model 865 loader has an overall height of only 26½ inches, in contrast to the 33 to 41½ inch heights of the three older models in the 660 series. Total power requirement of the new 865 loader is 60 horsepower, compared with 90 horsepower for the older models.

Power must be provided to drive three units—the digging chains on the gathering head, the conveyor which extends the length of the loader, and the tractor treads. Additionally, hydraulic cylinders control sidewise swing and vertical rise and fall of both the loading and discharge ends. For the front conveyor, the swing of 40 degrees to each side (36 degrees on the 660 series) is accommodated by a series of overlapping vertebrae, which also have guide strips at the bottom to hold down the conveyor flights. This construction is necessary since no central guide is used and the conveyor rises at a substantial angle just back of the front pivot point. For the discharge-end swing of 40 degrees from each side, flexible steel sides form a satisfactory guide for the conveyor chain.

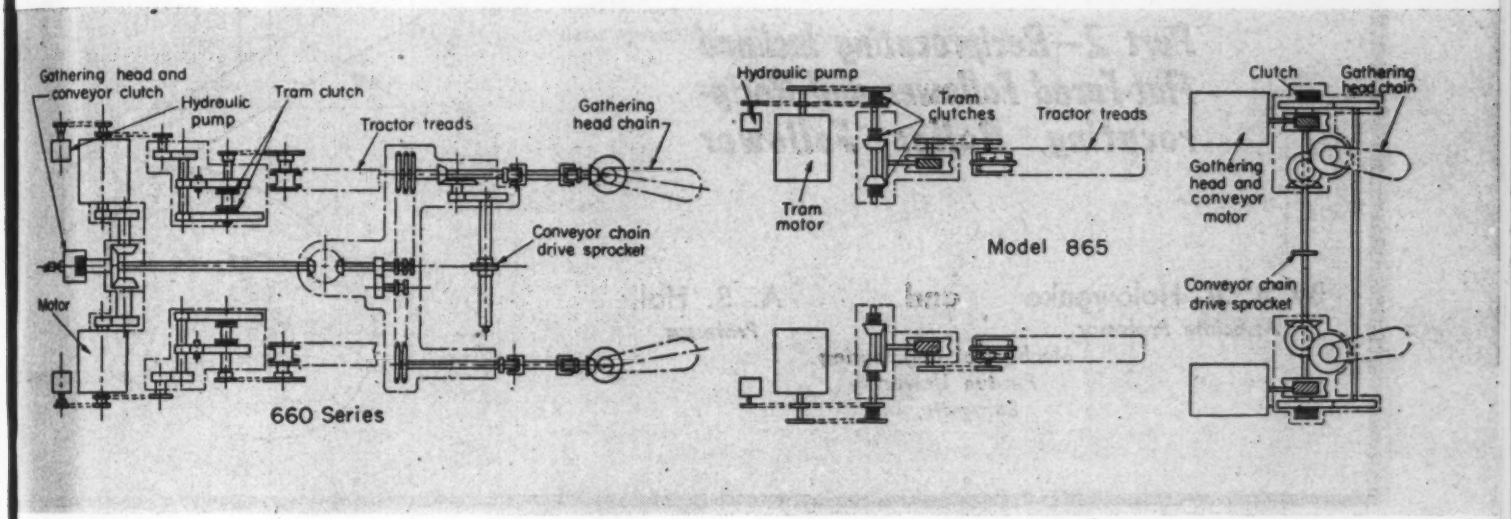


660 Series

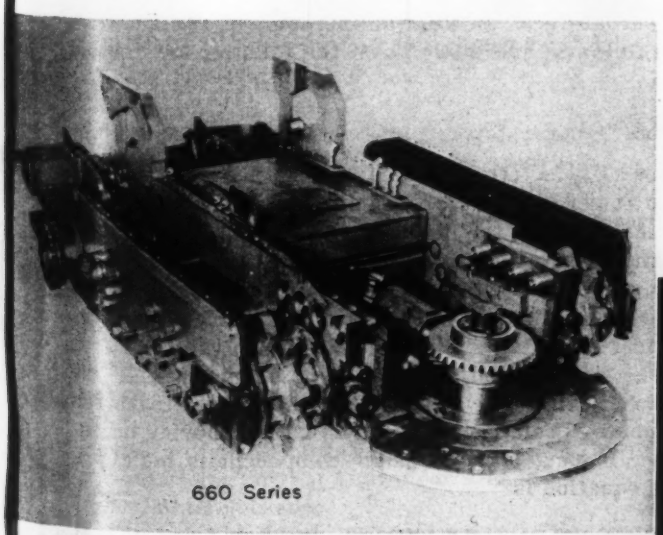


Model 865

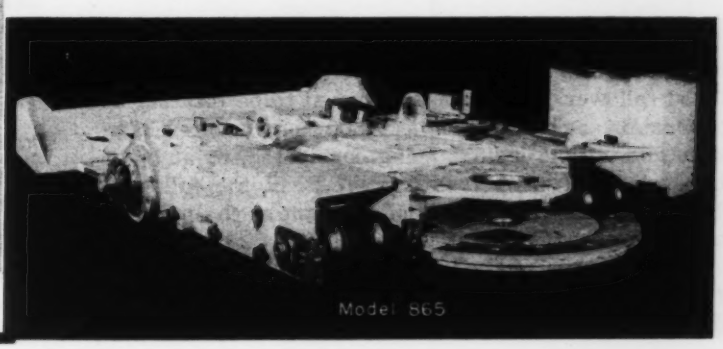
# Resigned to Eliminate Complex Transmission




Comparative simplicity that results from the use of four motors instead of two is very evident. On the older 660 series, two 45-horsepower motors coupled together drive the whole loader, with power for the conveyor and gathering-head chains being carried by a long shaft and relatively complex gearing. Two 10-horsepower motors with duplicate electrical parts connected in parallel drive the tractor treads for tramming on the 865 model, while power for the conveyor and gathering chains is provided by two 20-horsepower motors connected in series for equal current distribution. These two latter motors are coupled by a cross-shaft, and two constantly engaged safety clutches protect the gathering and conveying units in case of a jamup. A total of 30 horsepower is thus eliminated, and the characteristics of each motor can be fitted better to the particular load requirements. Two clutches are provided on both trams to drive each tractor tread independently in either direction.


660 Series

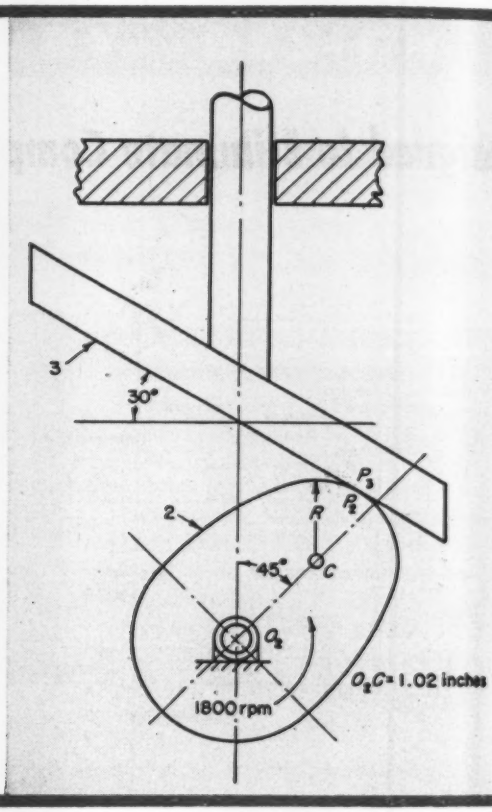
Frame height under the conveyor belt has been lowered considerably, since there are no mechanical transmission parts down the center of the 865 model, and a complex assembly—somewhat inaccessible and difficult to maintain—was eliminated. Critical transmission gearing on the 660 series at the pivot point for the loading head is also made unnecessary.


Model 865

# CAM CURVATURE

## *Part 2—Reciprocating Inclined Flat-Faced Follower and Reciprocating Roller Follower*

By A. R. Holowenko and A. S. Hall
*Associate Professor* *Professor*
*Mechanical Engineering*
*Purdue University*
*Lafayette, Ind.*




AS AN AID to both the analysis of cam motion and the determination of cam radius of curvature, this series of articles presents graphical methods, adaptable to exact calculations, for different types of disk cam systems. The first article (August issue) dealt with reciprocating in-line flat-faced follower systems. This article discusses reciprocating inclined flat-faced and reciprocating roller follower systems.

## Reciprocating Inclined Flat-Faced Follower

**Follower Motion:** *Fig.* 11*a* shows a cam of known contour working with a reciprocating inclined flat-faced follower. The cam is assumed to be rotating at a constant angular speed of 1800 rpm counterclockwise and, at the instant being considered, point $P_2$ of the cam is in contact with point $P_3$ of the follower. The radius of curvature $R$ of the cam at the point of contact is assumed to be known.

Although the analysis is similar to that for reciprocating in-line flat-faced followers, Part 1, there are differences in attack that merit attention.

A kinematically equivalent system is shown in *Fig.* 11*b* where the follower is pictured as being extended, while at the center of curvature of the point of contact of the cam in contact with the follower a slider is pictured as being introduced to work in the follower. The equivalence will hold as long as the radius of curvature of the cam is constant.

For a velocity analysis, the motion of two coincident points, point $C_2$ on the cam, where $C_2$ is the center of curvature of the cam at the point of contact with the follower, and point $C_3$ on the follower are related by

$$V_{C2} = V_{C3} \twoheadrightarrow V_{C2C3} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (9)$$

where $V_{C2} = (O_2C)\omega_2 = 1.02(1800)(2\pi)/12(60) = 16.0$ ft per sec; $V_{C3}$ = velocity of follower, known in direction, along the line of motion of the follower, but unknown in magnitude; $V_{C2C3}$ = relative velocity of two coincident points $C_2$ and $C_3$, known in direction, (parallel to the slot in *Fig.* 11*b*) but unknown in magnitude. *Fig.* 12*a* shows the velocity polygon.

The acceleration analysis may be made with the kinematically equivalent system, *Fig.* 11*b*. Inasmuch as point $C_2$ can be considered as a point moving on another moving body, Coriolis' component is indicated. The equation is

$$A_{C2} = A_{C3} \twoheadrightarrow {}_nA_{C2C3} \twoheadrightarrow {}_tA_{C2C3} \twoheadrightarrow {}_{cor}A_{C2C3} \quad \ldots\ldots\ldots (10)$$

where $A_{C2} = (O_2C_2)\omega_2{}^2 = 1.02[1800(2\pi)]^2/12(60)^2$

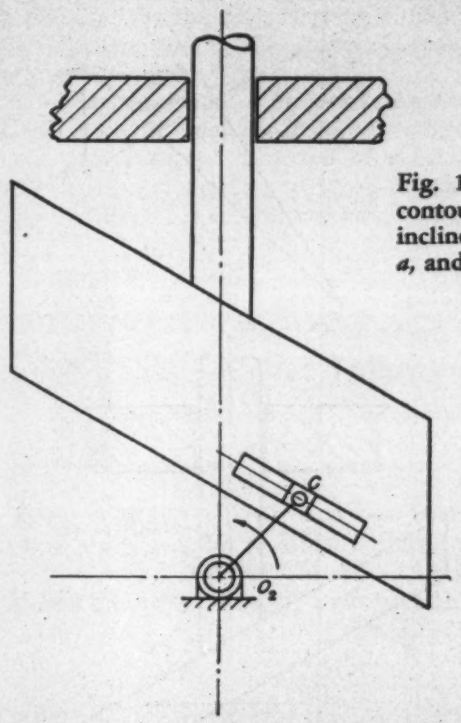



Fig. 11 — Cam of known contour with reciprocating inclined flat-faced follower, *a*, and kinematically equivalent system, *b*

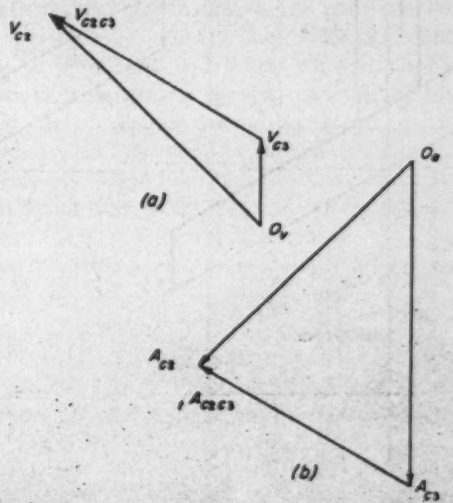



Fig. 12—Velocity polygon *a*, and acceleration polygon, *b*, for systems shown in *Fig.* 11

$=3020$ ft per sec$^2$; $A_{C3}$ = acceleration of follower, known in direction, along the line of motion of the follower, but unknown in magnitude; $_nA_{C2C3} = 0$; $_tA_{C2C3}$ is known in direction, parallel to the slot of *Fig.* 11*b*, but unknown in magnitude; $_{cor}A_{C2C3} = 2V_{C2C3}\omega_3 = 0$, since $\omega_3 = 0$. *Fig.* 12*b* shows the acceleration polygon.

For the selected data, link 3, the follower, is moving at a rate of 4.8 ft per sec and is accelerating at the rate of 3350 ft per sec$^2$ as determined from the velocity and acceleration analysis.

**Radius of Curvature:** The determination of the radius of curvature of the cam necessary for a prescribed motion of a reciprocating inclined flat-faced follower is comparable to that used with the reciprocating in-line flat-faced follower, Part 1, except for the variations to be shown.

The follower in *Fig.* 13*a* is known to be in a position where the velocity of the follower is 10 ft per sec upward, and the acceleration of the follower is 2000 ft per sec$^2$ downward. The problem is to determine the location of the center of curvature and the magnitude of the radius of curvature to satisfy the prescribed motion at the instant shown for a cam speed of 1800 rpm counterclockwise.

The two loci for the determination of the center of curvature are determined from a velocity and acceleration analysis. One locus for the center of curvature is found by obtaining the common normal to the cam and follower at the point of contact. The normal includes the instant center. The instant center, point *I* in *Fig.* 31, is $x$ distance from the center of the cam, on the horizontal. The distance $x$ is found from $x = V/\omega = 10(12)(60)/1800\ (2\pi) = 0.637$ inch. This factor allows determination of the point of contact of the cam and follower, or point $P_3$ of the follower is found.

The second locus for the center of curvature is found from the acceleration analysis. For this case, as for the reciprocating in-line flat-faced follower, a kinematically equivalent system will be used in the solution, even though the correct position of the center of curvature of the cam is not known. The equations for an acceleration solution are

$$A_{C2} = A_{P2} \twoheadrightarrow A_{C2P2} \quad \ldots\ldots (11)$$

$$A_{C2} = A_{C3} \twoheadrightarrow {}_nA_{C2C3} \twoheadrightarrow {}_tA_{C2C3} \twoheadrightarrow {}_{cor}A_{C2C3} \quad \ldots\ldots (12)$$

where $A_{C2}$ is unknown in direction and magnitude; $A_{P2} = (O_2P_2)\omega_2^2 = 2.18[1800(2\pi)]^2/12(60)^2 = 6450$ ft per sec$^2$ directed from $P_2$ to $O_2$; $A_{C2P2} = (C_2P_2)\omega_2^2$, unknown in magnitude since $C_2P_2$ is unknown, with point $C_2$ to be determined, but known in direction, along the line normal to the cam and follower; $A_{C3} = 2000$ ft per sec$^2$, originally specified; $_nA_{C2C3} = 0$; $_tA_{C2C3}$ is unknown in magnitude, but known in direc-

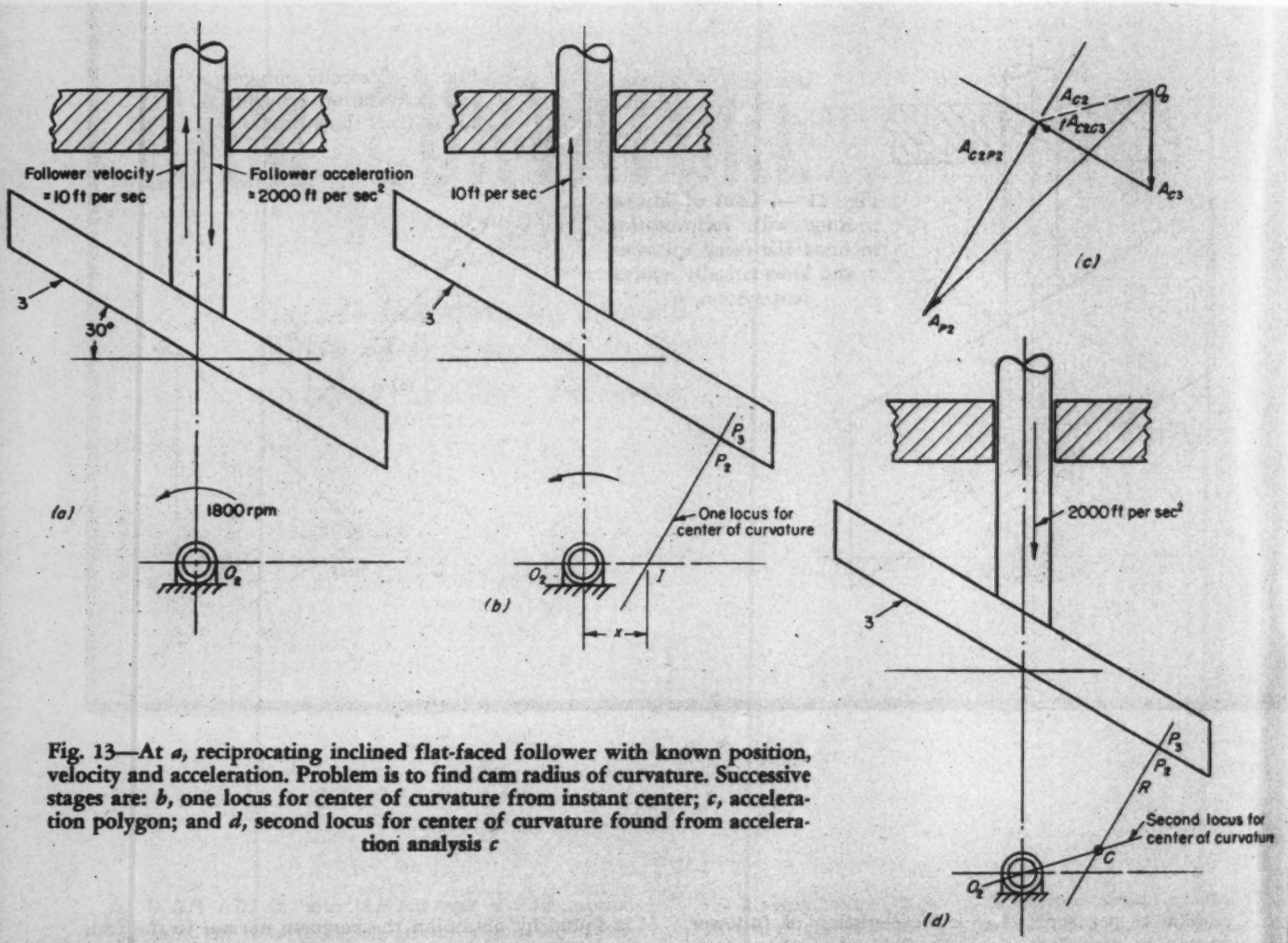



**Fig. 13—At *a*, reciprocating inclined flat-faced follower with known position, velocity and acceleration. Problem is to find cam radius of curvature. Successive stages are: *b*, one locus for center of curvature from instant center; *c*, acceleration polygon; and *d*, second locus for center of curvature found from acceleration analysis *c***

tion, parallel to the contact surface of the cam and follower; ${}_{cor}A_{C2C3} = 0$.

There are four unknowns in the two vector equations. A simultaneous solution of the equations, as done in *Fig.* 13*c* gives the solution for the four unknowns.

The second locus for the center of curvature can be drawn in *Fig.* 13*d*, parallel to $A_{C2}$ in the acceleration polygon to determine the center of curvature $C$. Or, the radius of curvature may be calculated, if desired, from $A_{C2P2} = (C_2P_2)\omega_2^2$. That is, $4500 = (C_2P_2)[1800(2\pi)]^2/(60)^2$ or $C_2P_2 = 0.127$ ft = 1.52 inches, where $C_2P_2 = R$.

**Exact Radius of Curvature:** The graphical analysis for velocity and acceleration affords one a means of obtaining an analytical expression for determining the radius of curvature. From *Fig.* 14*a*,

$$R + (O_2C)\sin\gamma = R_{bc} + \frac{L}{\cos\theta} \qquad (13)$$

where $R$ = radius of curvature; $\gamma$ = angle between the radial line from the center of rotation of the cam to the center of curvature and the line from the center of rotation of the cam perpendicular to the normal to the cam at the point of contact of the cam and follower, *Fig.* 14*a* (also, $\gamma$ is the angle between the acceleration of point $C_2$ and the relative acceleration of points $C_2$ and $C_3$, *Fig.* 14*b*); $R_{bc}$ = radius of the base circle; $L$ = lift; and $\theta$ = inclination of the contact surface of the follower.

From *Fig.* 14*b*, and with the law of sines, one may obtain

$$\frac{(O_2C)\,\omega_2^2}{\sin(90-\theta)} = \frac{A}{\sin\gamma}$$

from which

$$(O_2C)\sin\gamma = \frac{A\cos\theta}{\omega_2^2} \qquad (14)$$

Substitution of Equation 14 into Equation 13 gives

$$R = R_{bc} + \frac{L}{\cos\theta} - \frac{A\cos\theta}{\omega_2^2} \qquad (15)$$

where an acceleration downward is considered positive.

This equation may be handled in the same fashion as was that for the reciprocating in-line flat-faced follower in determining the minimum base circle radius for a given design.

The various cases for different direction of rotation of the cam, different direction of velocity of the follower, and different direction of acceleration of the follower are comparable to those for the system discussed in Part 1, and will not be considered.

## Reciprocating Roller Follower

**Follower Motion:** There are two common ways to analyze accelerations in a cam mechanism having a roller follower. One method makes use of an equivalent linkage and the other deals with the relative acceleration between the center of the roller and the coincident point on an extension of the cam. *Fig.* 15*a* shows a cam with reciprocating roller follower and *Fig.* 15*b* the equivalent linkage, in this case a simple slider-crank mechanism in which the rod connects the center of curvature, $C$, of the cam with the center of the roller. In *Fig.* 16*a* and *b* are shown the velocity and acceleration diagrams for the equivalent linkage, constructed for an assumed angular speed of the cam of 1800 rpm. The first step in the analysis is to compute the velocity of point $C$ of the cam from the angular velocity of the cam: $V_{C2} = (O_2C_2)\omega_2 = 0.725(1800)(2\pi)/12(60) = 11.38$ ft per sec.

Next, the velocity solution is completed by writing and solving

$$V_{P4} = V_{C2} + V_{P4C2} \qquad (16)$$

The direction of $V_{P4}$ is vertical and $V_{P4C2}$ is perpendicular to the line $CP$. With this information the ve-

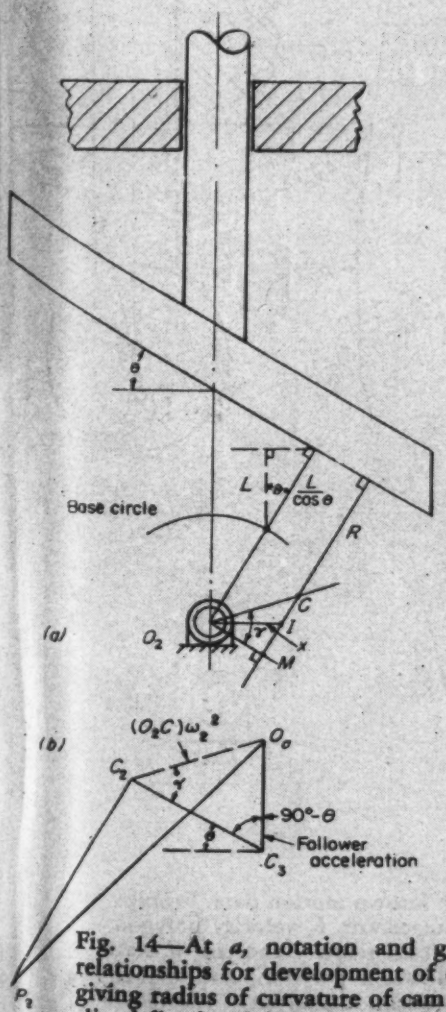



Fig. 14—At *a*, notation and geometric relationships for development of equation giving radius of curvature of cam with inclined flat-faced follower, and *b*, acceleration polygon showing trigonometric relationships

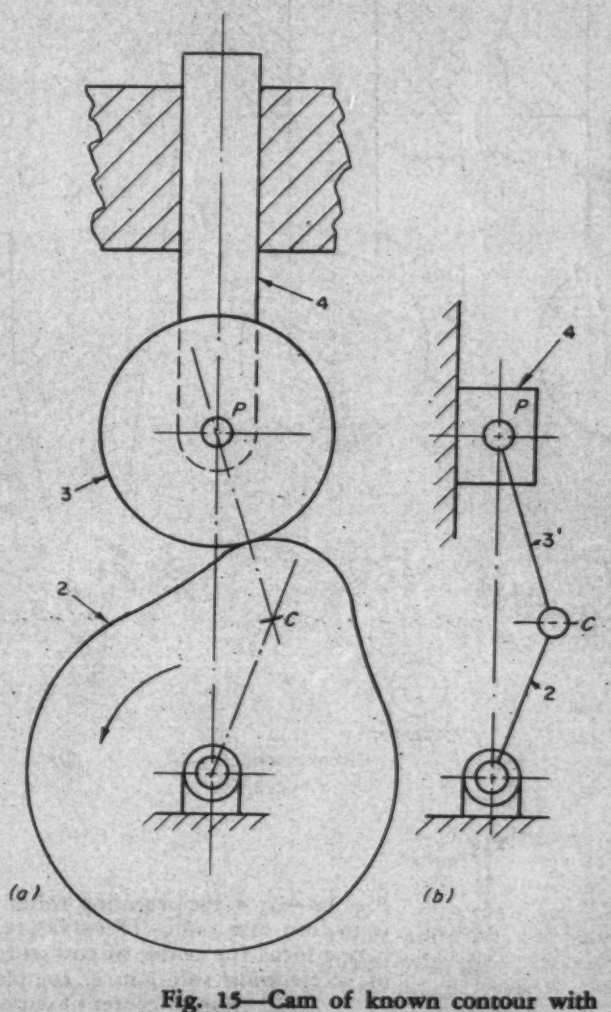



Fig. 15—Cam of known contour with reciprocating roller follower, *a*, and kinematically equivalent linkage, *b*

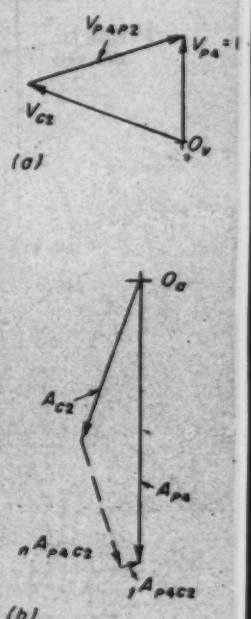



Fig. 16 — Velocity polygon, *a*, and acceleration polygon, *b*, for systems shown in *Fig.* 15

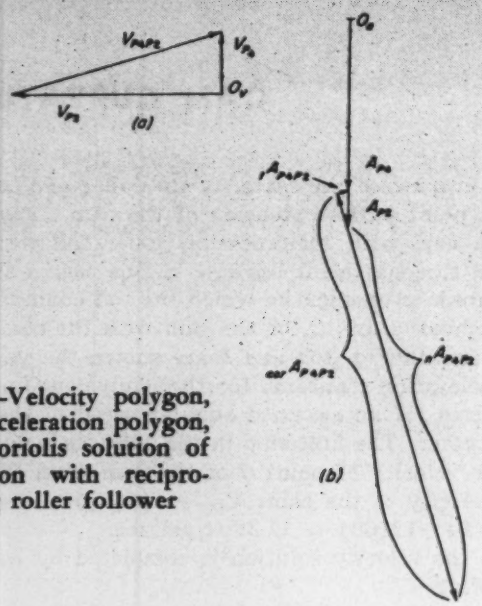


*Fig. 17*—Velocity polygon, *a*, and acceleration polygon, *b*, for Coriolis solution of acceleration with reciprocating roller follower

locity diagram is completed as shown in *Fig.* 16*a*.

The acceleration of point $C_2$ is next calculated: $A_{C2} = (O_2C_2)\omega_2^2 = 0.725[1800(2\pi)]^2/12(60)^2 = 2145$ ft per sec$^2$.

Acceleration $A_{P4}$ of the follower is found by solution of

$$A_{P4} = A_{C2} \twoheadrightarrow {}_nA_{P4C2} \twoheadrightarrow {}_tA_{P4C2} \quad \ldots\ldots\ldots\ldots\ldots\ldots (17)$$

In Equation 17 $A_{P4}$ is known in direction (along line of travel of follower), $A_{C2}$ is completely known (computed), ${}_tA_{P4C2}$ is known in direction (perpendicular to line $CP$), and ${}_nA_{P4C2}$ can be computed: ${}_nA_{P4C2} = (V_{P4C2})^2/(CP) = (11.12)^2(12)/0.850 = 1750$ ft per sec$^2$.

With this information the acceleration diagram can be completed as shown in *Fig.* 16*b*. While this is

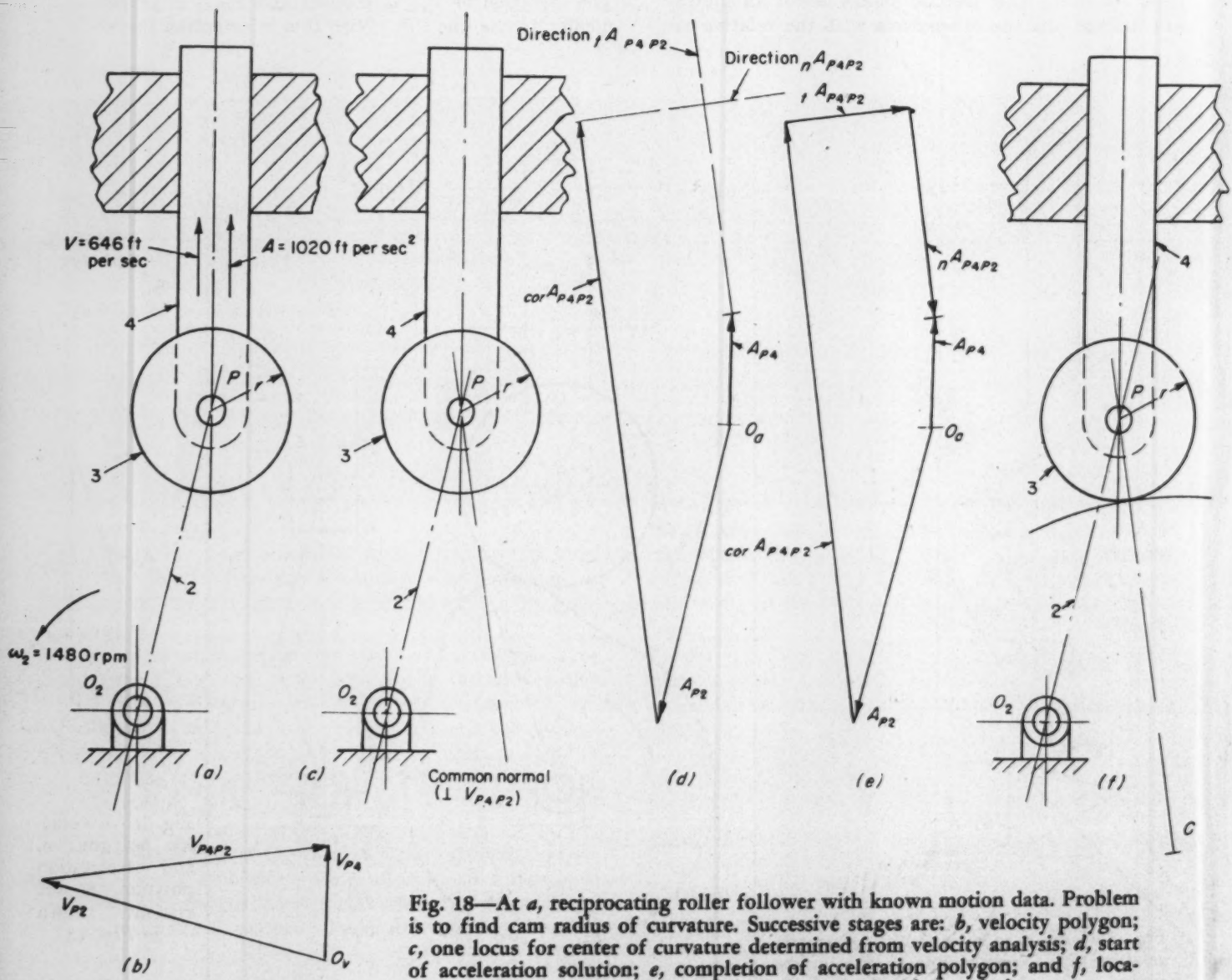






Fig. 18—At *a*, reciprocating roller follower with known motion data. Problem is to find cam radius of curvature. Successive stages are: *b*, velocity polygon; *c*, one locus for center of curvature determined from velocity analysis; *d*, start of acceleration solution; *e*, completion of acceleration polygon; and *f*, location of center of curvature from acceleration analysis

quite a neat process for finding follower acceleration when the center of curvature of the cam is available, it breaks down when the radius of curvature of the cam is so large that center $C$ cannot be marked on the drawing. A more generally usable procedure makes use of Coriolis' law.

In this solution attention is fixed on center $P_4$ of the follower and coincident point $P_2$ on an imaginary extension of the cam. First the velocity of point $P_2$ is calculated: $V_{P2} = (O_2P)\omega_2 = 1.492(1800)(2\pi)/12(60) = 23.45$ ft per sec. The velocity of $P_4$ is obtained from

$$V_{P4} = V_{P2} \twoheadrightarrow V_{P4P2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (18)$$

Since $V_{P4}$ is known to be directed along the line of travel of the follower, and relative velocity $V_{P4P2}$, is directed parallel to the common tangent between roller and cam, the velocity diagram is completed as shown in *Fig. 17a.*

For the acceleration solution, the following equation is used:

$$A_{P4} = A_{P2} \twoheadrightarrow {}_nA_{P4P2} \twoheadrightarrow {}_tA_{P4P2} \twoheadrightarrow {}_{cor}A_{P4P2} \quad \ldots\ldots\ldots\ldots (19)$$

In this equation, $A_{P2} = (O_2P)\omega_2^2 = 1.492[1800(2\pi)]^2/12(60)^2 = 4420$ ft per sec$^2$ directed from $P$ toward $O_2$; ${}_nA_{P4P2} = (V_{P4P2})^2/(CP) = (24.65)^2(12)/0.850 = 8580$ ft per sec$^2$ directed from $P$ toward $C$; ${}_{cor}A_{P4P2} = 2(V_{P4P2})\omega_2 = 2(24.65)(1800)(2\pi)/60 = 9300$ ft per sec$^2$ for which the direction is found by

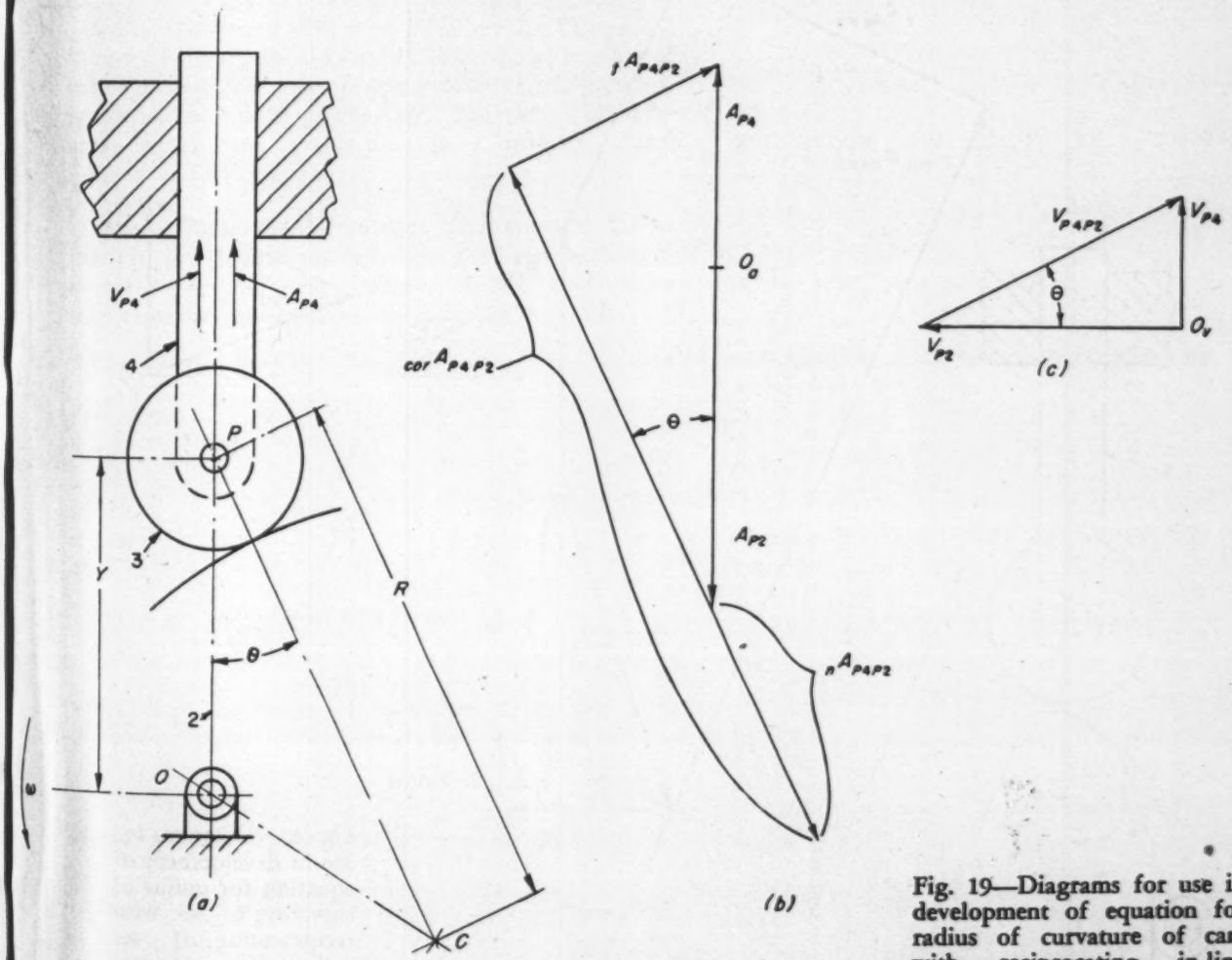



Fig. 19—Diagrams for use in development of equation for radius of curvature of cam with reciprocating in-line roller follower: *a*, geometric relationships; *b*, acceleration polygon; *c*, velocity polygon

rotating $V_{P4P2}$ vector 90 deg in the sense of $\omega_2$, giving in this case the Coriolis vector direction from $C$ toward $P$; ${}_tA_{P4P2}$ is known in direction only, parallel to the common tangent between roller and cam (perpendicular to $CP$); $A_{P4}$ is known in direction only, along line of travel of follower.

Construction of the acceleration diagram from this information is illustrated in *Fig.* 17*b*. From the starting point, $O_a$, the known vectors $A_{P2}$, ${}_nA_{P4P2}$ and ${}_{cor}A_{P4P2}$ are put down in order (added). Through the tip of the ${}_{cor}A_{P4P2}$ vector is drawn a line in the known direction of ${}_tA_{P4P2}$. From $O_a$ is drawn a line in the known direction of $A_{P4}$. The intersection of these lines gives the location of the tip of the $A_{P4}$ vector. Or, by measurement $A_{P4} = 3670$ ft per sec$^2$.

**Radius of Curvature:** The data shown in *Fig.* 18*a* will be used to illustrate the procedure for determining cam radius of curvature in the case of the reciprocating roller follower. The rotational speed of the cam, plus position, velocity and acceleration of the follower, are known. The location of the point of contact between roller and cam and the radius of curvature of the cam are unknown.

The first step is to calculate the velocity of point $P_2$: $V_{P2} = (O_2P)\omega_2 = 1.445(1480)(2\pi)/12(60) = 18.65$ ft per sec. The velocity diagram can then be constructed as shown in *Fig.* 18*b*. This layout determines the magnitude and direction of relative velocity $V_{P4P2}$. Since $V_{P4P2}$ is directed perpendicular to the common normal between cam and roller, this normal can now be drawn. At this stage of the process, the point of contact between cam and follower has therefore been located and a line (the common normal) on which the center of curvature of the cam must be located has been found, as illustrated in *Fig.* 18*c*.

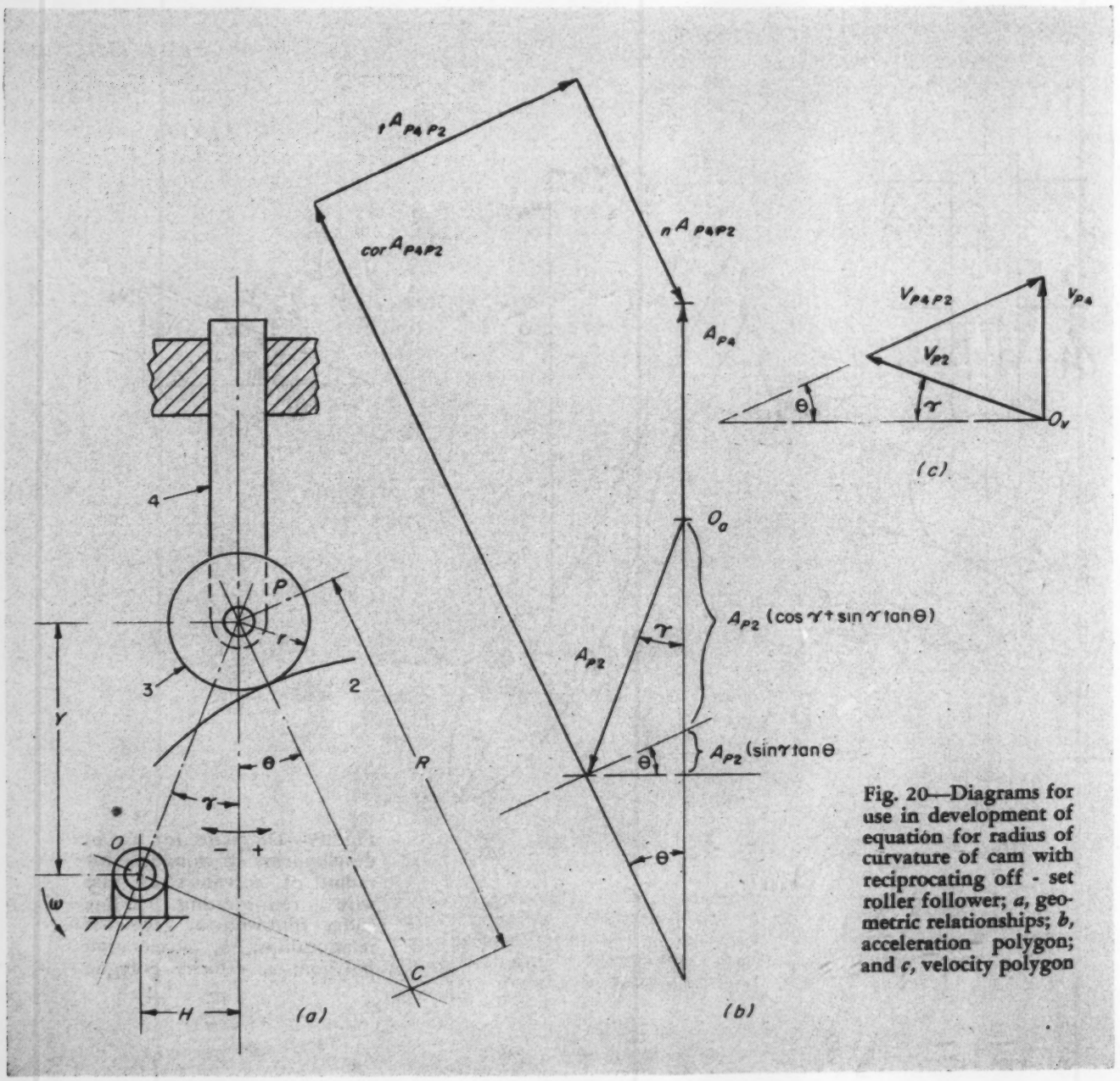



Fig. 20—Diagrams for use in development of equation for radius of curvature of cam with reciprocating off - set roller follower; *a*, geometric relationships; *b*, acceleration polygon; and *c*, velocity polygon

The process is continued with the acceleration equation,

$$A_{P4} = A_{P2} + {}_nA_{P4P2} + {}_tA_{P4P2} + {}_{cor}A_{P4P2} \quad (20)$$

where $A_{P4}$ is known (given); $A_{P2} = (O_2P)\omega_2^2 = 1.445\,[1480(2\pi)]^2/12(60)^2 = 2890$ ft per sec$^2$ directed from $P$ toward $O_2$; ${}_{cor}A_{P4P2} = 2(V_{P4P2})\omega_2 = 2(18.30)(1418)(2\pi)/60 = 5675$ ft per sec$^2$ directed along the common normal, upward from $P$; ${}_nA_{P4P2}$ is known in direction only, along the common normal; ${}_tA_{P4P2}$ is known in direction only, perpendicular to the common normal.

With this information, the acceleration diagram can be constructed. Starting at $O_a$ add the known vectors $A_{P2}$ and ${}_{cor}A_{P4P2}$. Also from $O_a$ lay out the the known vector $A_{P4}$, *Fig.* 18*d*.

Through the tip of the ${}_{cor}A_{P4P2}$ vector draw a line in the direction of the ${}_tA_{P4P2}$ vector. Through the tip of the $A_{P4}$ vector draw a line in the direction of the ${}_nA_{P4P2}$ vector. The intersection of these lines completes the acceleration diagram and gives the magnitude and sense for the ${}_nA_{P4P2}$ and ${}_tA_{P4P2}$ vectors, *Fig.* 18*e*.

In this example the value of ${}_nA_{P4P2}$ as scaled from the acceleration diagram is 1980 ft per sec$^2$. Since ${}_nA_{P4P2} = (V_{P4P2})^2/(CP)$, $CP = (V_{P4P2})^2/{}_nA_{P4P2} = (18.30)^2/1980 = 0.1692$ ft $= 2.030$ inches. The ${}_nA_{P4P2}$ vector always points from $P$ toward the center of curvature of the cam. Hence center of curvature $C$ is located as shown in *Fig.* 18*f*. The radius of curvature of the cam, in this case, is $(CP) - r = 2.020 - 0.375 = 1.655$ inches.

**Exact Radius of Curvature:** The notation to be used in developing an equation for cam radius of curvature in this case is shown in *Fig.* 19*a*. From inspection of the acceleration diagram, *Fig.* 19*b*,

$$(A_{P4} + A_{P2})\cos\theta = {}_{cor}A_{P4P2} - {}_nA_{P4P2} \quad (21)$$

but

$$A_{P2} = Y\omega^2 \quad (22)$$

where $Y$ = lift plus base circle radius plus roller radius.
Also,

$${}_nA_{P4P2} = \frac{(V_{P4P2})^2}{R} \quad (23)$$

where $R$ is the radius of curvature of the cam plus the roller radius. The Coriolis component is

$${}_{cor}A_{P4P2} = 2(V_{P4P2})\omega \quad (24)$$

With Equations 22 to 24 substituted in Equation 21,

$$(A_{P4} + Y\omega^2)\cos\theta = 2(V_{P4P2})\omega - \frac{(V_{P4P2})^2}{R} \quad (25)$$

Inspection of the velocity diagram as shown in *Fig.* 19*c* gives

$$V_{P4P2} = \frac{V_{P2}}{\cos\theta} = \frac{Y\omega}{\cos\theta} \quad (26)$$

When Equation 26 is substituted in Equation 25 and terms rearranged, the result is

$$\frac{1}{R} = \frac{2\cos\theta - \cos^3\theta}{Y} - \frac{A_{P4}}{Y^2\omega^2}\cos^3\theta \quad (27)$$

Angle $\theta$ can be evaluated from $\tan\theta = V_{P4}/Y\omega$.

For an offset reciprocating roller follower *Fig.* 20*a* identifies the quantities entering a derivation of the equation for radius of curvature. From the geometry of the acceleration polygon in *Fig.* 20*b*,

$$[A_{P4} + A_{P2}(\cos\gamma - \sin\gamma\tan\theta)]\cos\theta = {}_{cor}A_{P4P2} - {}_nA_{P4P2} \quad (28)$$

The following equations can be written:

$$A_{P2} = (OP)\omega^2 = \frac{Y}{\cos\gamma}\omega^2 \quad (29)$$

$${}_{cor}A_{P4P2} = 2(V_{P4P2})\omega \quad (30)$$

$${}_nA_{P4P2} = \frac{(V_{P4P2})^2}{R} \quad (31)$$

Substituting these equations into Equation 28 gives

$$\left[A_{P4} + \frac{Y\omega^2}{\cos\gamma}(\cos\gamma + \sin\gamma\tan\theta)\right]\cos\theta = 2(V_{P4P2})\omega - \frac{(V_{P4P2})^2}{R} \quad (32)$$

Inspection of the velocity vector diagram in *Fig.* 20*c* shows that $V_{P4P2}\cos\theta = V_{P2}\cos\gamma$. Hence,

$$V_{P4P2} = \frac{V_{P2}\cos\gamma}{\cos\theta} = \frac{Y\omega}{\cos\theta} \quad (33)$$

Substituting Equation 33 into Equation 32 and simplifying,

$$(A_{P4} + Y\omega^2 - Y\omega^2\tan\gamma\tan\theta)\cos\theta = \frac{2Y\omega^2}{\cos\theta} - \frac{Y^2\omega^2}{R\cos^2\theta} \quad (34)$$

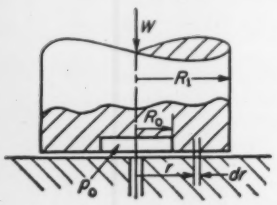
Finally, solving for $1/R$ gives

$$\frac{1}{R} = \frac{2\cos\theta - (1 + \tan\gamma\tan\theta)\cos^3\theta}{Y} - \frac{A_{P4}\cos^3\theta}{Y^2\omega^2} \quad (35)$$

where $\tan\gamma = -H/Y$, $\tan\theta = (V_{P4}/Y\omega) - H/Y$, $Y = \sqrt{(R_{bc}+r)^2 - H^2} + L$, $R_{bc}$ = base circle radius, $r$ = roller radius, $H$ = offset, and $L$ = lift.

The final article of this series, to appear in the November issue, will discuss systems employing oscillating-roller and flat-faced followers, and a reciprocating roller follower with reciprocating cam.

Fig. 1—Elements of a hydrostatic flat step thrust bearing




# A Look at Hydrostatic Thrust Bearings

By Frank R. Archibald
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SIMPLE in concept, hydrostatic thrust bearings can readily be analyzed by straightforward procedures. The flat step bearing, *Fig.* 1, is well known and has been treated in detail by others[1, 2]. Extension of these principles to a bearing having a conical seat seems to offer the possibilities of lateral constraint as well as thrust capacity and will be discussed here. Attention will also be given to the load capacity of a bearing employing a spherical seat.

For viscous fluid flow in the flat step bearing of *Fig.* 1, it can easily be shown that lubricant pressure must satisfy the equation,

$$p = p_0 \frac{\log_e \left( \frac{R_1}{r} \right)}{\log_e \left( \frac{R_1}{R_0} \right)} \qquad (1)$$

where $p$ is the lubricant pressure at some radius $r$ and other symbols are defined in *Fig.* 1. Load capacity of the bearing is given by

$$W = \frac{\pi p_0 (R_1^2 - R_0^2)}{2 \log_e \left( \frac{R_1}{R_0} \right)} \qquad (2)$$

Equations 1 and 2 are also fundamental equations for the conical seated bearing, *Fig.* 2*a*. Substitution of slant distances obtained from a development of the conical section for the radii merely results in a reiteration of Equations 1 and 2. The slant distances, as shown in *Fig.* 2*b* and indicated by primes, are $R_0' = R_0/\sin \phi$, $R_1' = R_1/\sin \phi$ and $r' = r/\sin \phi$.

For the spherical seated bearing, *Fig.* 3, a film of constant thickness will be assumed; when the bearing is under load the centers of the spherical seat and the ball are coincident. This assumption simplifies analysis and seems to give good results. Lubricant pressure is

$$p = p_0 \frac{\log_e \left[ \frac{\sin \phi_1}{\sin \phi} \left( \frac{1 - \cos \phi}{1 - \cos \phi_1} \right) \right]}{\log_e \left[ \frac{\sin \phi_1}{\sin \phi_0} \left( \frac{1 - \cos \phi_0}{1 - \cos \phi_1} \right) \right]} \qquad (3)$$

where $p$ is the lubricant pressure at some angle $\phi$ and other symbols are defined in *Fig.* 3. Load capacity of this bearing is

$$W = \frac{\pi p_0 R^2 (\cos \phi_0 - \cos \phi_1)}{\log_e \left[ \frac{\tan \left( \frac{\phi_1}{2} \right)}{\tan \left( \frac{\phi_0}{2} \right)} \right]} \qquad (4)$$

The validity of Equations 3 and 4 has been demonstrated by tests on a model spherical bearing[2]. A steel ball 6 inches in diameter and weighing 31.88 pounds was supported in a cup with $\phi_0 = 39$ deg and $\phi_1 = 56\frac{1}{2}$ deg. From Equation 4

$$p_0 = \frac{31.88 \left[ \log_e \left( \frac{\tan 28° 15'}{\tan 19° 30'} \right) \right]}{9 \pi (\cos 39° - \cos 56° 30')} = 2.09 \text{ psi}$$

Actual observed pressure necessary to "float" the ball was 2.07 psi.

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1. Lord Rayleigh—"A Simple Problem in Forced Lubrication," *Engineering* (Great Britain), December 14 and December 28, 1917.
2. Dudley D. Fuller—"Hydrostatic Lubrication," MACHINE DESIGN, June, July, August, September, 1947.

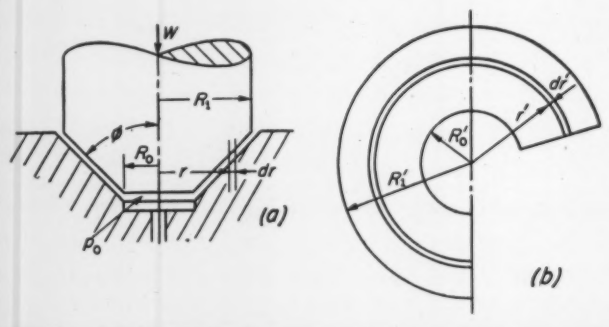


Fig. 2—Left — Hydrostatic thrust bearing with conical seat showing *a*, bearing elements and *b*, development of conical surfaces

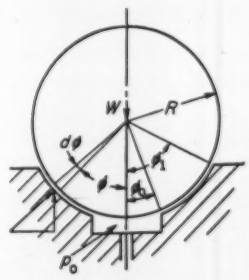


Fig. 3—Right—Elements of a spherical seated hydrostatic thrust bearing

# AN EXACT

# Computing Linkage

***. . . based upon a single-link mechanism which generates the ancient cissoid of Diocles***

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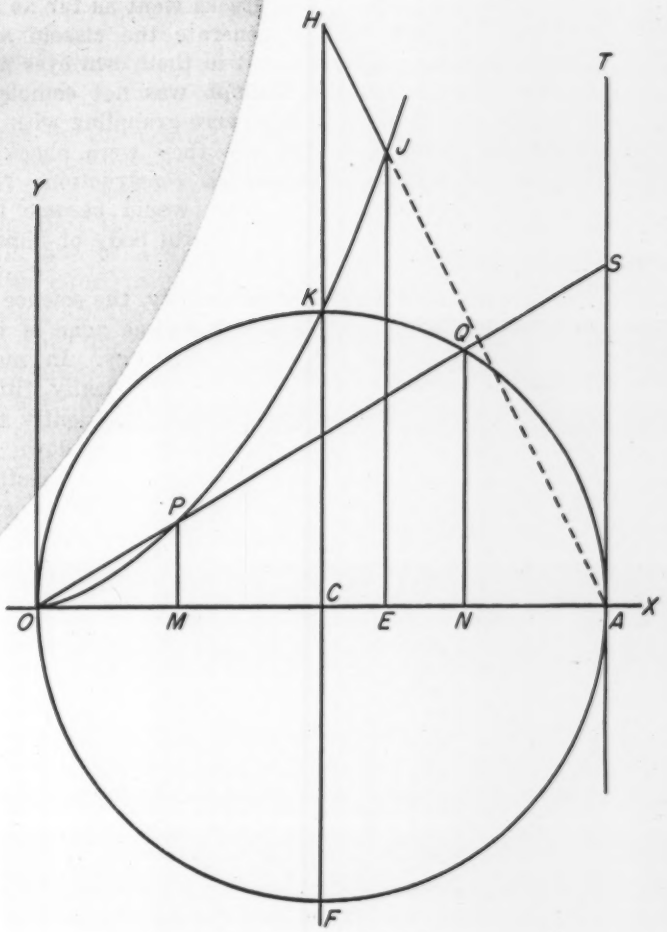



Fig. 1—The cissoid is the locus of point *P*; $OP = QS$ and line *OS* revolves about point *O*

IN THE history of Greek geometry, there are several variations of the story of the origin of the problem of duplicating the cube. One story relates that Athens was struck by a ravaging plague in 430 B. C. The citizens, frightened and discouraged, consulted the oracle at Delos for advice in placating the angry gods. The oracle cryptically suggested that the cubical altar to Apollo be replaced by a new altar with double the cubic content of the old one. Distinguished geometers hastened to solve the problem and suggested as a first try a cube with edge double that of the old, but found to their surprise that the volume was eight times that of the original. No one knows whether the gods were angered by this evidence of professional incompetence or whether they mitigated the plague with godlike tolerance of man's ignorance. At any rate, the story is intriguing whether true or not, and it is said that the city recovered and prospered but the altar of appeasement was never built.

The Delian problem of doubling the cube persisted for centuries. Joined by its sister problems of trisecting an angle and constructing a square equal in area to a given circle, the cube problem was a beloved frustration for mathematicians until its relatively recent illumination by modern analysis. The core of the difficulty was that as heirs to the geometry of Euclid the Greeks were bound by the severe restrictions of Euclidean construction, namely, the use of only a straightedge and compass. It was sacred law that these constructions be so performed. And we have learned since that these tools are inadequate for exact solutions of the problem. Although many approximate solutions of amazing accuracy have been and continue to be given, the problems have not been solved in the spirit of their original conception. It has been rigorously shown[1] that it is impossible to solve three problems exactly with only a straightedge and a compass as tools.

The cube problem led to several fruitful blind alleys. One of these concerns the cissoid of Diocles. It is not certain just when Diocles lived; it is very probable that it was in the last half of the second century B. C. or in the beginning of the first century B. C. Diocles invented the curve in the search for a solution to the problem of doubling the cube. Although the curve permits the solution of the prob-

lem, the failure of the construction and the frustration of Diocles are that the curve cannot be constructed by straightedge and compass alone. As many points on the curve as desired can be obtained with the two basic Euclidean tools, but to obtain all points on the curve would require an indefinitely large number of constructions, or an instrument other than the two of Euclid. Indeed, the Greeks went as far as inventing a mechanism[2] to generate the cissoid and demonstrate its properties, but in their own eyes and by Euclid's criteria the triumph was not complete. They did not know that they were grappling with an insolvable problem so long as they were shackled by the restrictions of Euclidean construction. Nor did they know that their quest would become the foundation for an elegant and useful body of human knowledge.

In present day computer technology, the science of designing linkages and mechanisms has none of the aesthetic perfection of Greek geometry. In most cases, an approximate device is empirically fitted to the desired function generation. Frequently the final device must have its errors trimmed down by introducing correcting cams, eccentrics and adjusting links, and the range of operation is often strictly limited.[3] Nor is there a unified body of design information or a general procedure for the mechanical synthesis of functional relationships.[4] The present state of the art is that the understanding of the mathematical kinematicians and the geometers has not filtered down to the level of practical application. Practitioners admit that experience and an intuitive feel are important advantages. Almanacs[5] have proven to be of value and various simple linkages are handled quite well by graphical or analytical methods. Certain mechanisms have been studied and exploited only after having been discovered by accident.

This article describes an exact linkage which is based upon a known generator of the cissoid of Diocles. The linkage may be used to obtain several output displacements which are interesting functions of an input displacement. It is suggested that other usable displacement transforming properties may be found inherent in mechanizations of some of the other higher order plane curves. It seems to be worth while to hunt for exact solutions in the realm of analytic geometry in the hope that in special cases they may offer advantages not to be found in the presently used procedures.

The cissoid may be defined[6] as follows: let *OFAK* in *Fig.* 1 be a circle centered at *C*, of radius *a*, with *OA* a diameter and *AT* a tangent; draw any line as *OQS* through *O*, meeting the circle in *Q* and the tangent in *S*. On this line lay off $OP = QS$. The locus of point *P* as the line *OS* revolves about *O* is the cissoid.

From this definition, the equation of the cissoid in

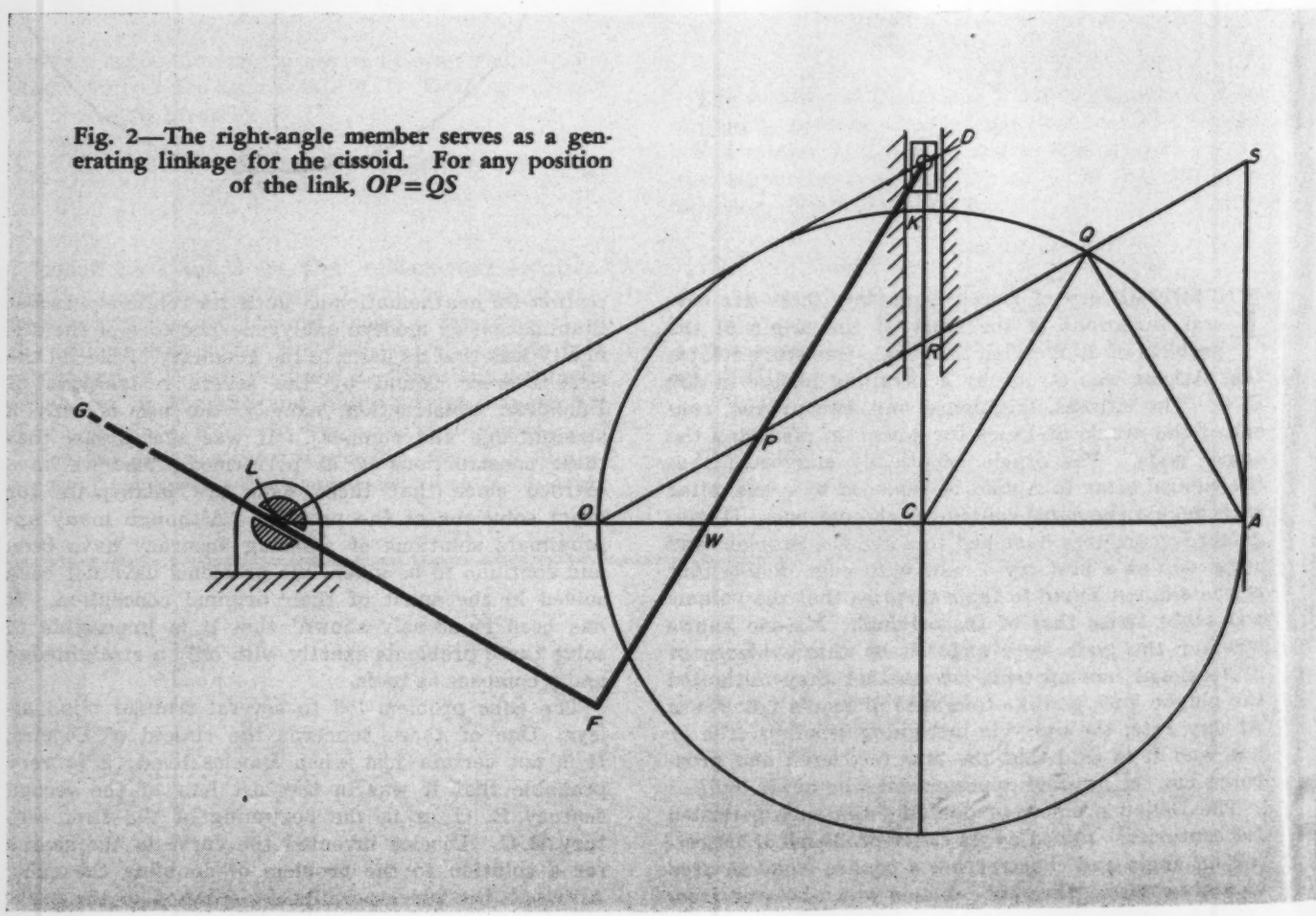



**Fig. 2—The right-angle member serves as a generating linkage for the cissoid. For any position of the link, $OP = QS$**

rectangular co-ordinates relative to axes $OX$ and $OY$ is obtained. Let the co-ordinates of $P$ in *Fig.* 1 be $x$ and $y$ and let

$$OC = CA = a$$

Since triangles $OMP$ and $ONQ$ are similar,

$$\frac{MP}{OM} = \frac{NQ}{ON} \quad \ldots\ldots (1)$$

and since $OP = QS$,

$$NA = OM = x$$

Moreover,

$$(NQ)^2 = (ON)(NA) = (2a - x)x$$

since $OQA$ is a right triangle. Substituting these values in Equation 1 gives

$$\frac{y}{x} = \frac{\sqrt{(2a - x)x}}{2a - x}$$

or

$$y^2 = \frac{x^3}{2a - x} \quad \ldots\ldots (2)$$

Use of the cissoid to duplicate the cube can be demonstrated as follows: Extend $CK$ to $H$ making $CK = HK = a$, draw line $HA$ cutting the cissoid at $J$, and draw the ordinate $EJ$. Since $CA = \frac{1}{2}(CH)$, then $EA = \frac{1}{2}(EJ)$, but from Equation 2,

$$(EJ)^2 = \frac{(OE)^3}{(EA)} = \frac{(OE)^3}{\frac{1}{2}(EJ)}$$

Therefore,

$$(EJ)^3 = 2(OE)^3$$

which is the desired relation between the edges of the respective cubes. Note that only point $J$ of the cissoid is useful in this way.

In 1951 the Russian kinematician I. I. Artobolevskii[7], one of a group of Russian workers devoting major effort to calculating linkages, proposed a generating linkage for the cissoid as a basis for obtaining the cube or cube root of a number. In *Fig.* 2, a right-angle link $DFG$ with length $DF = 2a$ and side $FG$ indefinite in extent moves so that point $D$ is on line $CK$ or its extension while the other leg always passes through a point $L$, where $L$ is on the extension of line $AO$, a distance $a$ from point $O$. Then point $P$ which is half way between $F$ and $D$ will trace one branch of the cissoid. This truth can be demonstrated quite simply by showing that $OP = QS$, the essential geometric condition for the curve in *Fig.* 1.

Extend line $OP$, *Fig.* 2, to its intersection with the

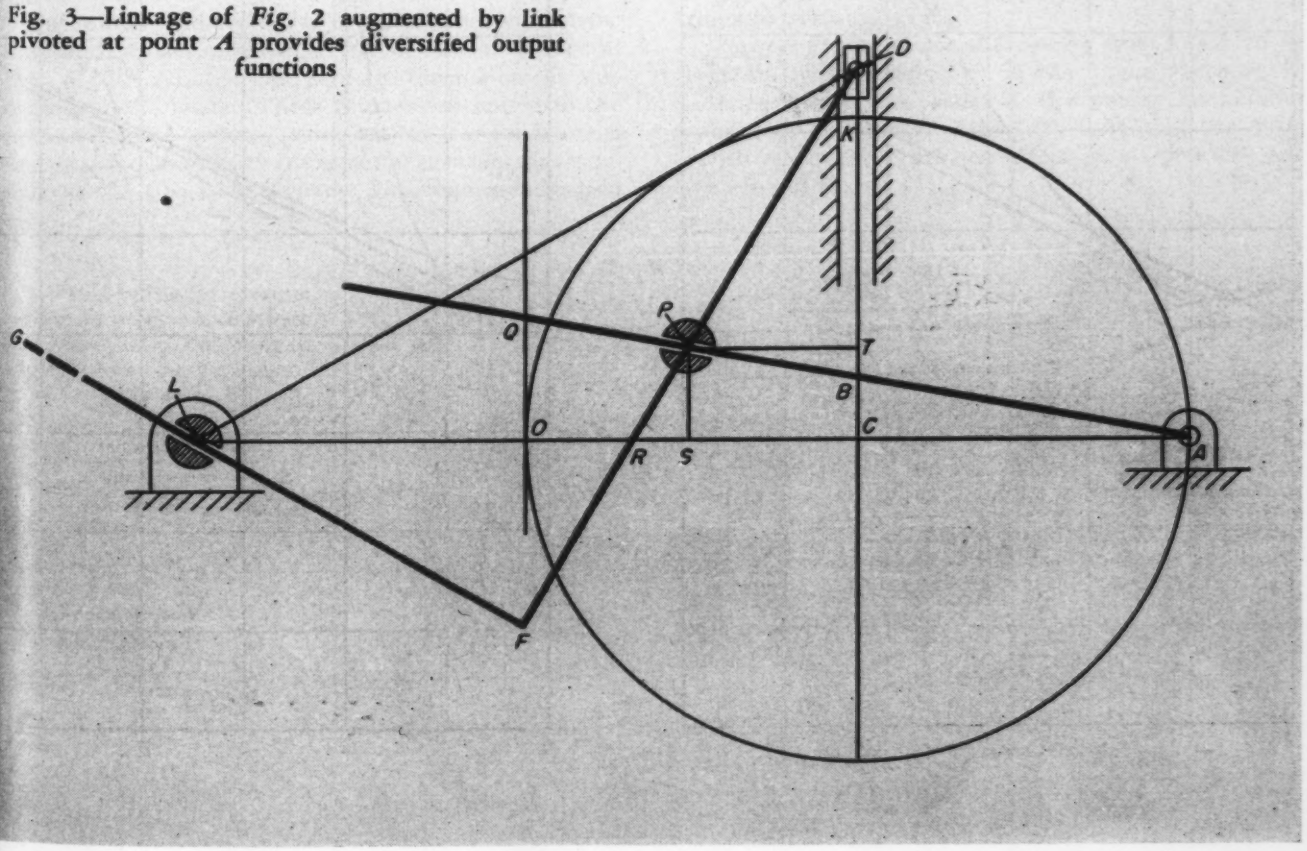



Fig. 3—Linkage of *Fig.* 2 augmented by link pivoted at point $A$ provides diversified output functions

diameter $CK$ at $R$, with the circle at $Q$ and with the tangent at $S$. Draw $QA$ and $CQ$.

Triangle $OCQ$ is isosceles since $OC = CQ = a$. Therefore angle $COQ$ = angle $CQO$. Triangle $LFD$ is congruent to triangle $DCL$ since both are right triangles with a common hypotenuse and one leg of length $2a$. Then angle $DLW$ = angle $LDW$. Hence triangle $LWD$ is isosceles as is also triangle $OWP$ since $LO = PD$. Then angle $WOP = COQ = WPO$ and as opposite angles, angle $WPO$ = angle $RPD$.

From the foregoing relationships, angle $RPD$ = angle $CQO$. Also $PD = QC = a$ and, as opposite angles, angle $PRD$ = angle $CRQ$. Thus triangle $PRD$ is congruent with triangle $QRC$ and $PR = RQ$. Since $OR = RS$, then by subtraction, $OP = QS$. Thus the geometric definition of the cissoid is shown to exist.

Artobolevskii adds to this known mechanism a lever pivoted at $A$, *Fig.* 3, and passing through point $P$ which describes the cissoid Now, if the distance $CD$ is considered to be the input motion $x$, and if for convenience distance $2a$ is assumed unit distance, than it can readily be shown by elementary geometry that the following relations are true:

$$CD = LF = x \qquad FR = RC = \frac{1 - x^2}{2}$$

$$RP = OR = \frac{x^2}{2} \qquad PT = \frac{1 - x^2}{2(1 + x^2)}$$

$$OQ = x^3$$

$$AS = \frac{1}{1 + x^2} \qquad AP = \frac{\sqrt{1 + x^6}}{1 + x^2}$$

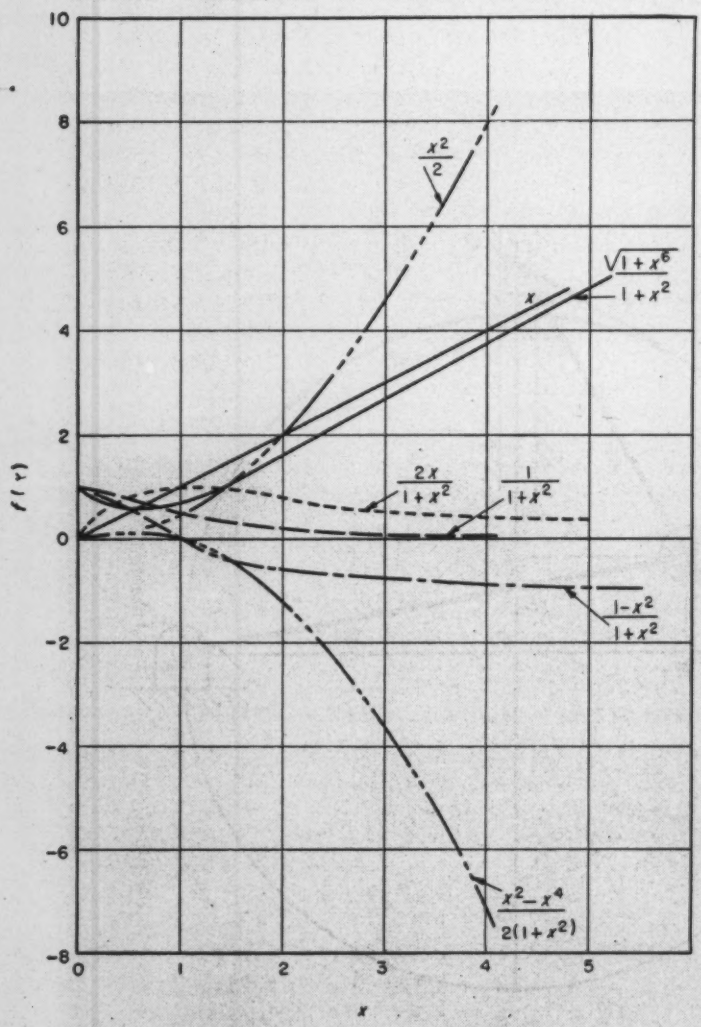
$$SP = \frac{x^3}{1 + x^2} \qquad LD = \sqrt{1 + x^2}$$

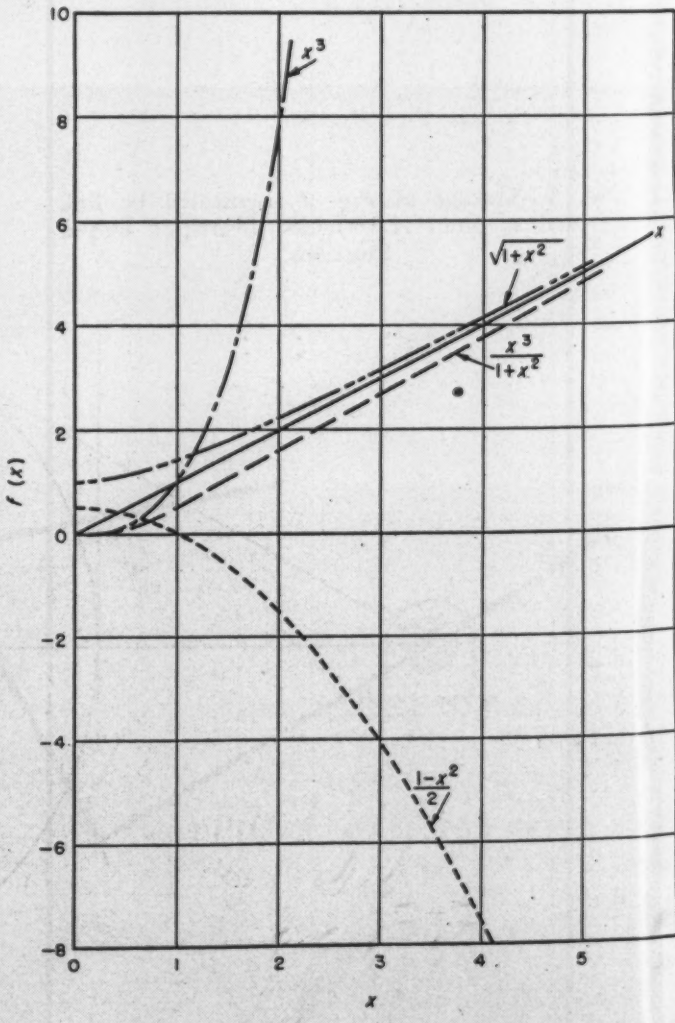
$$\sin OLF = \frac{1 - x^2}{1 + x^2} \qquad RS = \frac{x^2 - x^4}{2(1 + x^2)}$$

$$\cos OLF = \frac{2x}{1 + x^2} \qquad TB = \frac{x^3 - x^5}{2(1 + x^2)}$$

Several of these output displacement functions

Fig. 4—Curves of typical functions generated exactly by linkage of *Fig.* 3



are shown in *Fig.* 4 which illustrates the wide variety of shapes obtainable. It is apparent that the linkage range of operation is not limited, nor is there any mechanical locking except very close to $x = 0$. It is possible to conceive a displacement other than distance *CD* acting as the input, so that inverse functions may likewise be generated. This suggests the possibility of obtaining 1/3, 1/2, 2/3, and 3/2 powers and more complicated inversions of the functions just listed. It seems that a servo-driven linkage like the one described may readily be instrumented to perform a fairly accurate computing task with the aid of components such as rotational or linear potentiometers, resolvers, optical levers, calibrated springs, capacitances, or inductive elements.

If it is desired to generate a function similar in shape to any of those shown here, it may possibly be done by empirically changing the pivot point *A*, the distance *DF*, the location of point *P* on *DF*, the position of point *L*, or the relative spacing of points *O* and *C*. One may thus introduce just enough distortion to fit the linkage output to the desired empirical function. However, the distortion of the linkage may cause mechanical locking or loss of a portion of the range of the original device.

As this article suggests, answers to linkage computing problems may sometimes be found in the field of geometry, particularly in devices which generate higher order plane curves by continuous motion.

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# Hydraulic Torque Loader Facilitates Gear Testing

TESTING marine turbine reduction gears by the back-to-back, or circulating torque, method has been facilitated by development of a hydraulic torque loader which permits the application of a known torque while the gears are running. Position of the torque loader developed by the Parsons and Marine Engineering Turbine Research and Development Association in a typical test set-up is in the shaft joining pinions or gears of the test gear sets.

The torque loader, *Fig.* 1, consists of an inner vane ring, with vanes attached to either side of a central disk. A pair of outer vane sets are formed on the side flanges of the loader. These flanges are bolted to the circumferential cover, inside which the inner vane ring can move with as little radial clearance as possible at the tips of the vanes. The chambers formed between each alternate pair of inner and outer vanes are filled with high-pressure oil, led in through a hydraulic slip-ring. The oil exerts pressure on the vanes forming the sides of the chamber and produces a torque between the outer and inner vane rings.

The torque varies directly with the pressure difference between the high-pressure and low-pressure chambers. To measure this difference, gage pipes are led directly from the oil chambers by way of the slip rings to pressure gages.

Torque produced by the loader was found to be limited by the capacity of the pump, because of leakage across the ends of the vanes. Leakage is caused by expansion of the drum holding the outer vanes under the combined effect of oil pressure and centrifugal force.

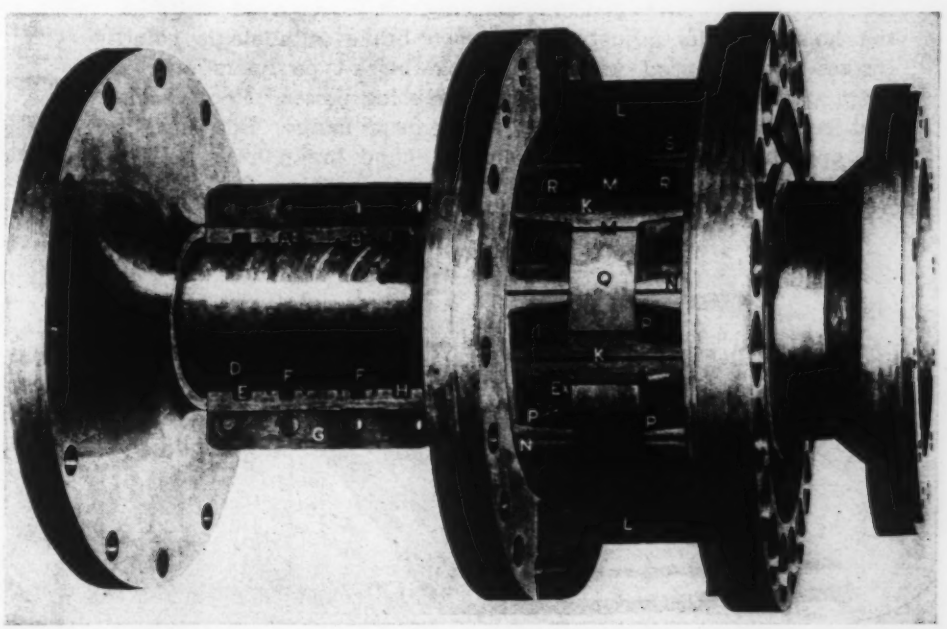
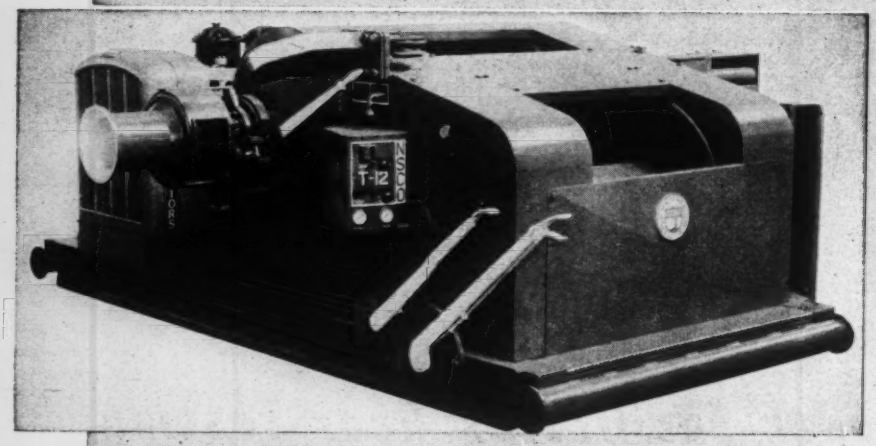


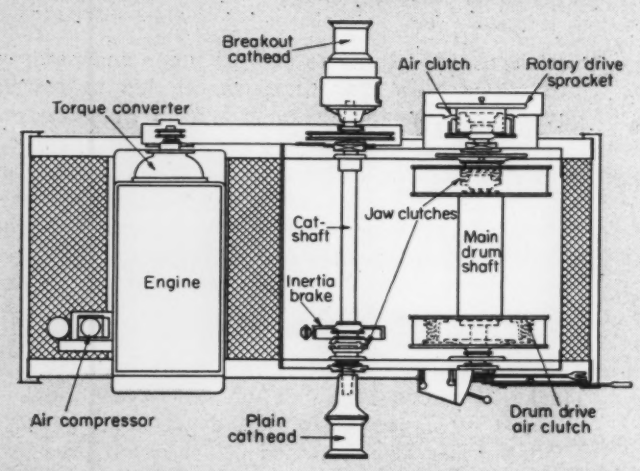

Fig. 1—Hydraulic torque loader permits applications of torques to 15,000 lb-ft at 4100 rpm during reduction-gear tests

A—Low-pressure gage groove
B—High-pressure gage groove
C—High-pressure feed hole
D—Low-pressure outlet hole
E—Low-pressure outlet groove
F—Guard groove
G—Hydraulic slip ring
H—High-pressure inlet groove
I—Inlet hole
K—Sealing grooves
L—Cover
M—Equalizing grooves
N—Outer vanes
O—Exhaust hole
P—Stops
Q—Inner vane ring
R—High-pressure oil chamber
S—Low-pressure oil chamber

# Compact Drive for Drilling Hoist

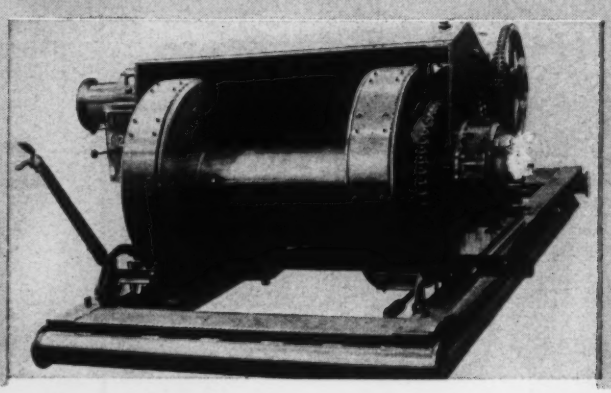


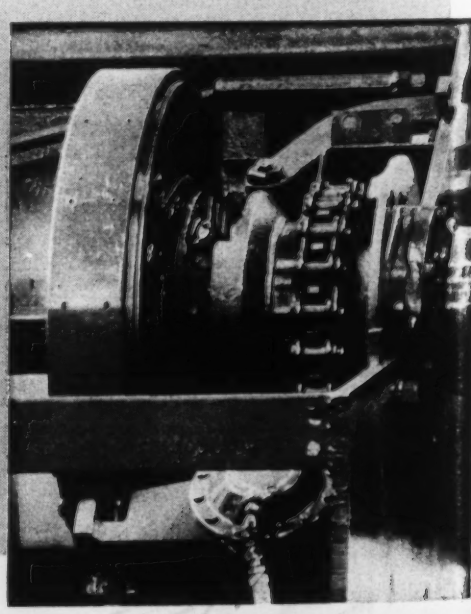

A COMPACT, versatile drive system is one of the main features of the Ideal T-12 drilling hoist of National Supply Co. An engine-mounted torque converter provides highest efficiency at low main-drum speeds, permitting the 120-horsepower engine to operate at 80 per cent of governed speed even when the converter output shaft is completely stalled. The catshaft, on which a sand reel (a second drum) can be mounted is driven by a double 1-inch pitch chain from the converter. Two single 1¾-inch pitch chain drives from the catshaft to the main drum permit engine output to be applied in two speed ranges; two mechanical jaw clutches and an air clutch permit selection of either range. A second air clutch is used on the rotary drive to the drill pipe.




An air-actuated inertia brake on the catshaft quickly stops all rotating parts while speed changes are being made and prevents creep from the slight drag transmitted through the torque converter by the idling engine. The brake is interlocked with the air-operated engine throttle so that power cannot be applied while the brake is engaged. Also shown is one of the mechanical jaw clutches.

Main drum brakes are of a new design, specifically developed for the hoist. An equalizing mechanism, located in back of the hoist, permits adjustment of each brake at a single point. Brakes are equipped with replaceable block-type liners over a large angle of wrap, providing high snubbing power. Replaceable cast-iron brake rims are mounted on the drum flange. Both brakes are operated by a single conventional hand brake lever, and a built-in piping system is included for water-spray cooling of the rims.





# Graphical Methods for Determining BEAM DEFLECTIONS

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WHEN shafts or beams are subjected to various loads arranged in a random manner, the resulting deflections are usually difficult to determine mathematically. Calculation complexity is magnified if the cross-section varies along the length of the shaft or beam. In such a case, handbook formulas for beam deflections have little value because they are derived for definite load arrangements and constant cross-sections. Even the well known moment-area and conjugate-beam methods become cumbersome under the foregoing conditions.

To avoid purely analytical methods which usually become complex, this data sheet outlines graphical techniques for determining shaft or beam deflection. Two forms are presented—a semigraphical method and a graphical method.

**Uniform Cross-section Beams:** Comparison of the analytical method with the semigraphical and graphical methods is provided by solutions to a problem involving a uniform cross-section beam or shaft with two supports and four concentrated loads. Deflections are obtained at the four load points by the three methods in *Figs.* 1, 2, 3.

In an analytical approach to this problem, the number of loads and their arrangement preclude utilization of only one equation for solution of the deflections. Therefore the principle of superposing deflections can be applied here. Algebraic addition of deflections produced at any one point by each load acting separately provides the total deflection at that point. This involves setting up and solving 16 equations for this problem.

Analytical determination of maximum deflection presents an involved problem because the point of maximum deflection for each load is dependent upon the position of that load. To obtain the maximum deflection, deflection curves for the entire length of the beam for each load acting separately must be plotted for at least ten points along the beam to get a representative curve. The load arrangements in *Fig.* 1 require the solution of 40 equations. The resulting deflection curves from each separate load must be added algebraically to obtain a deflection curve produced by the combined load forces from which the maximum deflection can be determined. Maximum deflection as determined by the semigraphical method is shown in *Fig.* 2 and by the graphical method in *Fig.* 3.

When a comparison is made of the three methods for obtaining maximum deflection, the results show that:

1. If the analytical method were considered correct, error in deflection by the semigraphical method was 0.0017 in. and by the graphical approach was 0.0008 in. It is not to be construed from these figures that the graphical method is twice as accurate as the semigraphical but rather that in both methods deflection errors are small in value.
2. Time required to determine the deflection curve by the analytical method was 8 hours while by the semigraphical and graphical methods it was 6 and 2 hours, respectively.
3. Moment diagrams and slope curves are obtained additionally by the two graphical methods.

**Stepped Shafts:** The fully graphical method is most advantageous when solving beam deflections of stepped shafts. A problem is solved by this technique in *Fig.* 4 for a stepped shaft. The procedure for determining

the deflection curve is identical with that for a uniform cross-section shaft except in the treatment of the *M/EI* diagram at the point where the shaft diameters change.

**Couples:** In *Fig.* 5 there is a worm shaft problem shown that involves a combination of a couple and two vertical forces in the same plane of the couple. The moment diagram for the couple is considered separate from the moment diagram for the vertical forces. The two curves are plotted with reference to the same base line and then added algebraically to provide the combined moment diagram. The *M/EI* diagram is then developed and from this the deflection curve is obtained in the previously described manner.

**Cantilever Beams:** A cantilever beam problem is solved graphically in *Fig.* 6. The solutions for beam deflections is again identical to that outlined previously with one important exception. In the layout of the string polygon for the deflection diagram, the pole (in this case $O_3$) must lie on the horizontal projection of the base line of the slope diagram.

**Conclusions:** In the analytical method using superposition of deflections to find deflections at the loads, the number of equations varies as the square of the number of forces. With many forces, this method becomes extremely complicated and with stepped shafts practically impossible.

Problems with couples become quite involved with the analytical method. In the graphical method the moment diagrams for the couples and other forces are simply added to obtain the total moment diagram for the shaft. Then the *M/EI* diagram and deflection curve are readily obtained.

In any problem dealing with shafts and beams the entire history of the reactions and moments is normally required in addition to the deflections to complete a theoretical analysis. With the analytical method, the determination of reactions and moments require additional work while with the graphical methods these quantities appear as part of the overall solution for beam deflections. The latter method also provides a deflection curve for the entire length of the beam thus affording rapid appraisal of the critical sections which the analytical method cannot provide without long and tedious calculations.

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Fig. 1—Analytical solution of deflections at load points and maximum deflection of a shaft having a constant circular cross-section with two supports and four concentrated loads. Solution procedure:

1. Consider shaft as having a single load $W$ of 84 lb at the end with both ends overhanging. Calculate resulting deflection at the load from the standard equation, $y = Wc^2 (c+L)/3EI = 84 (7.437)^2 (7.437 + 20)/3 (30) (10)^6 (0.0491) = 0.0289$ in.
2. Consider the 164-lb load acting alone on the shaft and find the deflection it produces at the 84-lb load.
3. Find the deflection at the 84-lb load point produced by each of the other loads acting separately.
4. Repeat this procedure for all the other load points by applying the proper handbook formulas.
5. Algebraically add deflections produced at any one point by each load, obtaining total deflection at that point.
6. To obtain maximum deflection value, algebraically add deflection curves produced by each load acting separately for at least 10 points along overall length of beam.

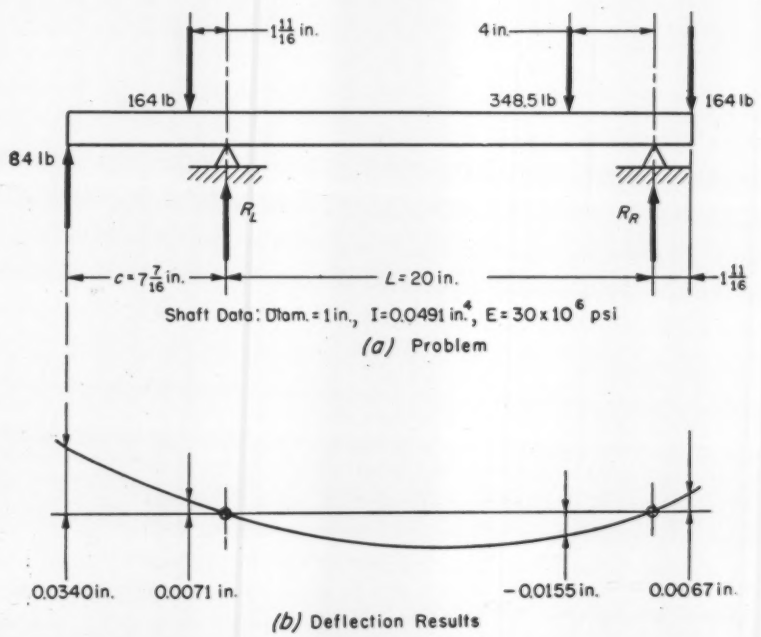


Fig. 2—Semigraphical solution of deflections at load points and maximum deflection of a shaft having a constant circular cross-section with two supports and four concentrated loads. Solution procedure:

1. Draw beam to scale showing loads, pertinent dimensions, and lines of action, *a*.

2. Make force polygon representing loads drawn to scale, *b*. For clarity, draw upward and downward forces and reactions on separate lines. Draw strings from line of action from which first force is drawn. Locate pole $O_1$ any convenient distance $H_1$.

3. Form moment diagram from force polygon. Draw string 1 in the force polygon between the 84-lb load and the left support, $R_L$. Draw a ray parallel to string 1 between the line of action of the 84-lb load and line of action of the left support to initiate the formation of the moment diagram, *c*. Repeat this process for the remaining strings through 5 which should be drawn between the line of action of the 164-lb load and the right support. Draw ray 6 in the moment diagram between the two supports to close the diagram. If moment diagram does not close, there is a couple in the system.

4. Rearrange the moment diagram on a horizontal base line by transposing vertical elements, *d*.

5. Form the *M/EI* diagram, *e*, by dividing the bending moments of diagram *d* by *EI* and plotting these values from base line $X_2X_2$.

6. Divide the *M/EI* diagram, *e*, into geometrical shapes by vertical lines to permit easy determination of the areas.

7. From base line $X_4X_4$ plot to scale the magnitude of area $A_1$ as the ordinate $a_1b_1$. Plot sum of areas $A_1$ and $A_2$ as ordinate $c_1d_1$. Curve $X_4E_1T$ is formed in this manner and represents the first integral curve or slope diagram.

8. Establish the point of zero slope or maximum deflection between the ends of the beam by the mean ordinate of curve $X_4E_1T$. Obtain this mean ordinate by dividing area $X_4E_1TX_4$ by the length of the base line $X_4X_4$. Any ordinate to the curve $X_4E_1T$ from the mean ordinate line $X_3E_1X_3$, which is drawn perpendicular to the mean ordinate, represents the actual slope at that point.

9. Determine the beam deflection curve by laying off reference line *JL* and from this line plot to scale the magnitude of area $X_3g_1b_1X_4$ (area $B_1$) as ordinate $a_2b_2$. The magnitude of area $X_3h_1d_1X_4$ (areas $B_1$ and $B_2$) is plotted as ordinate $c_2d_2$. Thus the areas between the mean ordinate line $X_3E_1X_3$ and the slope curve $X_4E_1T$ are accumulated algebraically and become the ordinates of deflection curve $JE_2L$.

10. Draw neutral axis line $X_5X_5$ through the deflection curve at the points of beam support. Obtain deflections by scaling vertical distances between $X_5X_5$ and $JE_2L$.

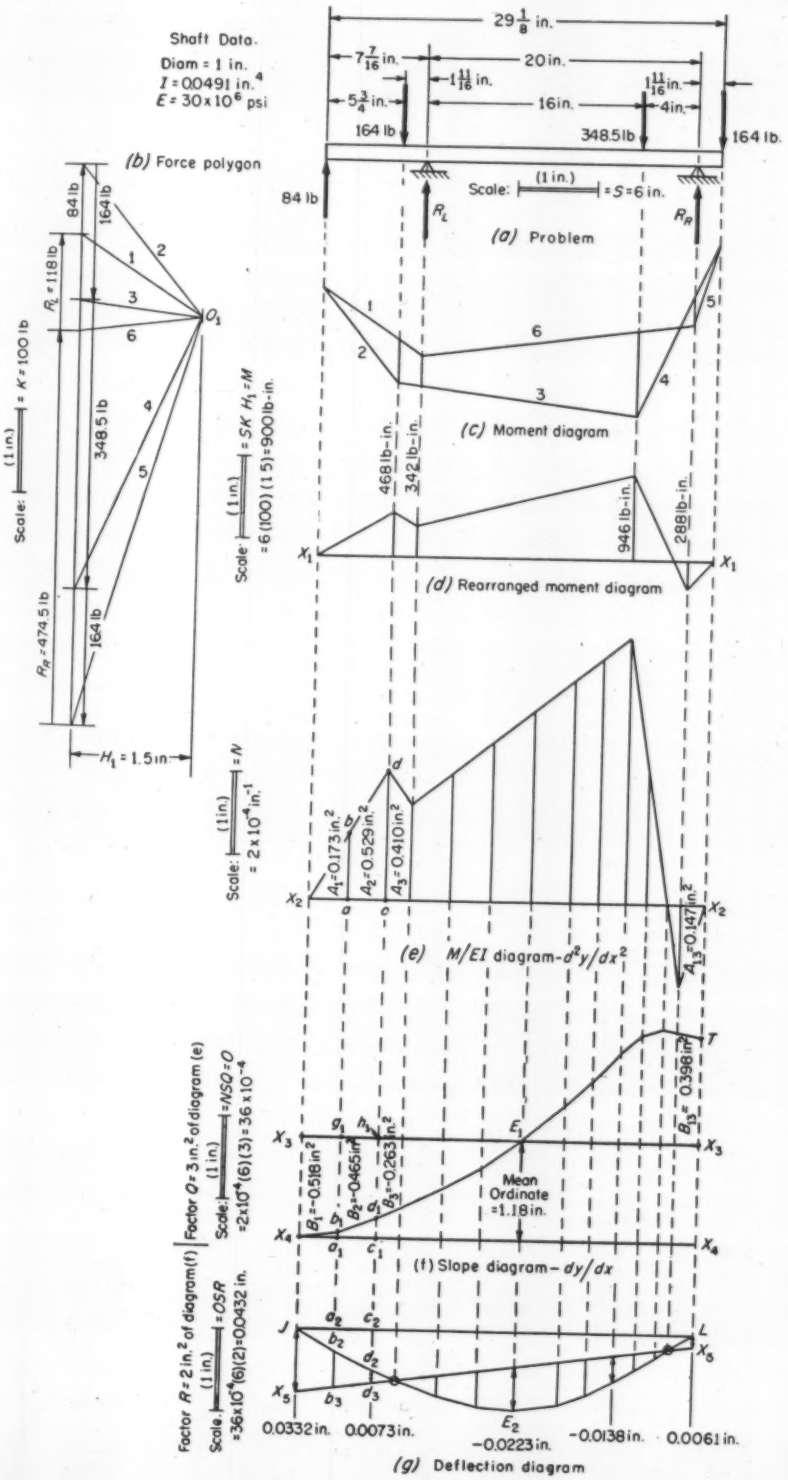


Fig. 3—Fully graphical solution of deflections at load points and maximum deflection of a shaft having a constant circular cross-section with two supports and four concentrated loads. The solution procedure is the same as described in the semi-graphical system in *Fig.* 2 for steps 1 through 5.

6. Divide the $M/EI$ diagram, $e$, into convenient segments as shown. Mark the mean ordinates of each segment 1, 2, 3, . . . 12.

7. To one side erect a vertical line parallel to the ordinates of $M/EI$ diagram $e$. Project horizontally the mean ordinate points 1, 2, 3, etc., to this line. To the left of the vertical line at a convenient distance $H_2$ place pole $O_2$ on the horizontal projection of base line $X_2X_2$. Complete the string polygon by joining pole $O_2$ with the points 1, 2, 3, etc., on the vertical line.

8. Draw base line $X_3X_3$. From the left-hand end of line $X_3X_3$ draw $X_3a$ parallel to string $O_21$. Next draw $ab$ parallel to $O_22$, and continue this procedure until the entire slope curve in diagram $f$ is formed.

9. Determine the mean ordinates of the segments for slope diagram $f$, and designate them 1′, 2′, 3′, . . . 12′ as shown.

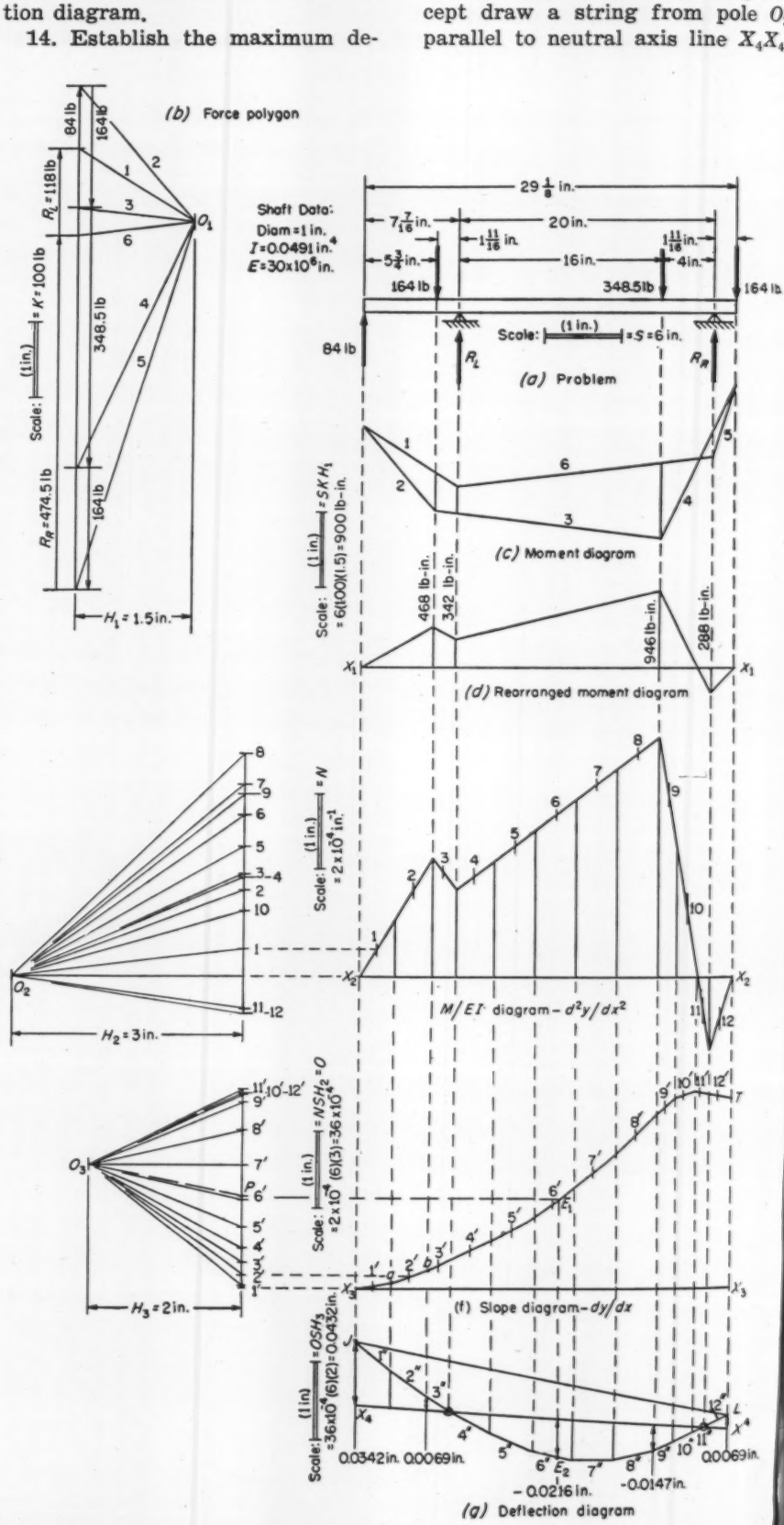
10. Construct a string polygon in the same manner as outlined in step 7 with the exception that pole $O_3$ need have no definite relationship to the base line $X_3X_3$.

11. Obtain the deflection curve $JE_2L$ shown in diagram $g$ by drawing line 1″ parallel to $O_31'$, line 2″ parallel to $O_32'$, and continue this procedure until the curve is completed.

12. Draw neutral axis line $X_4X_4$ through the deflection curve at the points of beam support. Any ordinate between the deflection curve and neutral axis line measured to scale will represent the deflection at that point.

13. Establish the maximum deflection point between the ends by drawing a straight line from $J$ to $L$. Draw string $O_3P$ parallel to $JL$. From $P$ draw a horizontal line until the slope curve is intersected at $E_1$. Drop a vertical line down to $E_2$ which locates the maximum deflection ordinate on the deflection diagram.

14. Establish the maximum deflection point between the supports by repeating the previous step except draw a string from pole $O_3$ parallel to neutral axis line $X_4X_4$.



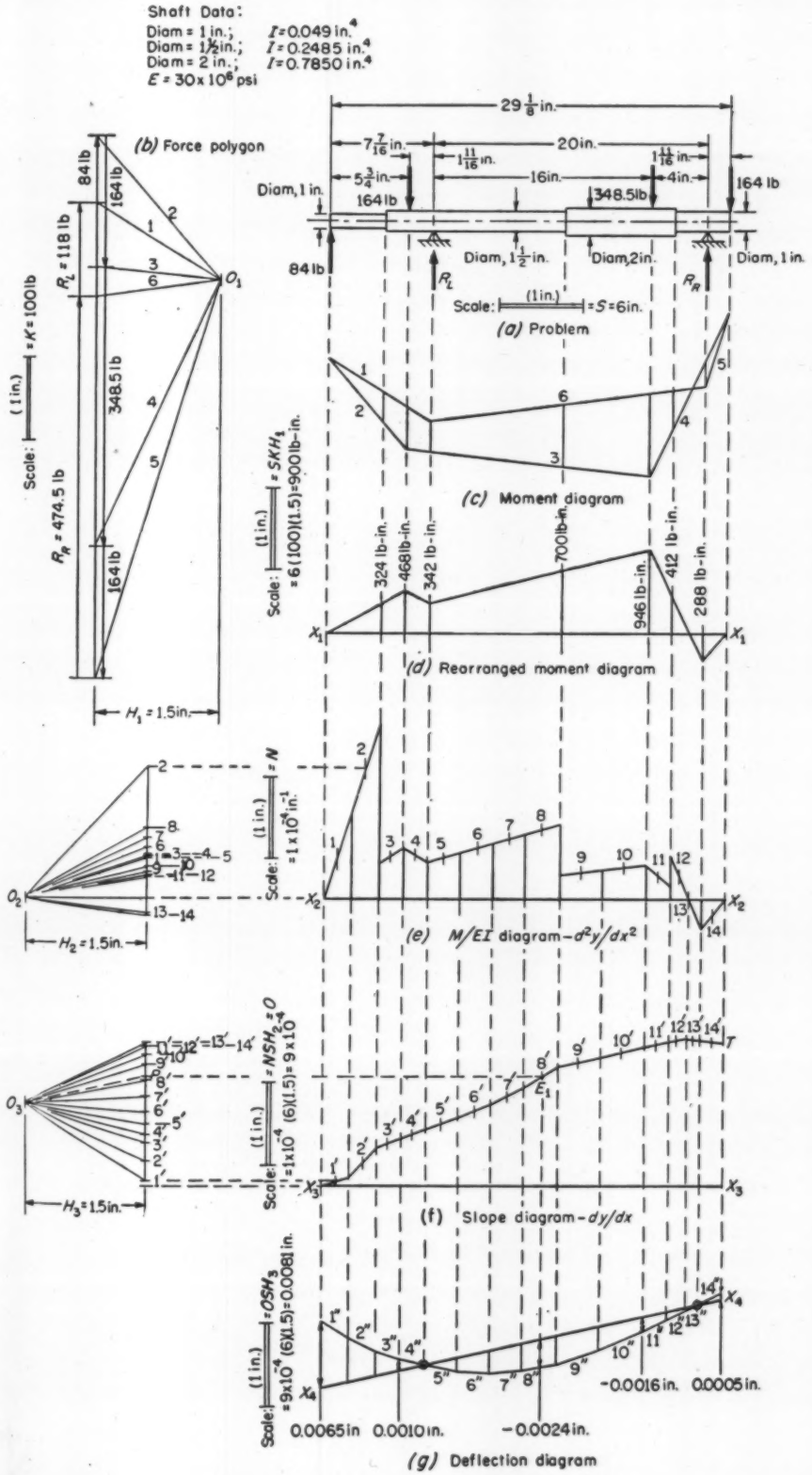



**Fig. 4—Fully graphical solution of the deflections at load points and maximum deflection of a stepped shaft having circular cross - sections with two supports and four concentrated loads. Solution procedure is identical as that outlined under the fully graphical method in *Fig.* 3 except for one variation. In the treatment of the *M/EI* diagram at the point where the shaft diameters change, two points are plotted on the same ordinate—one for each shaft diameter since *I* is different for each.**

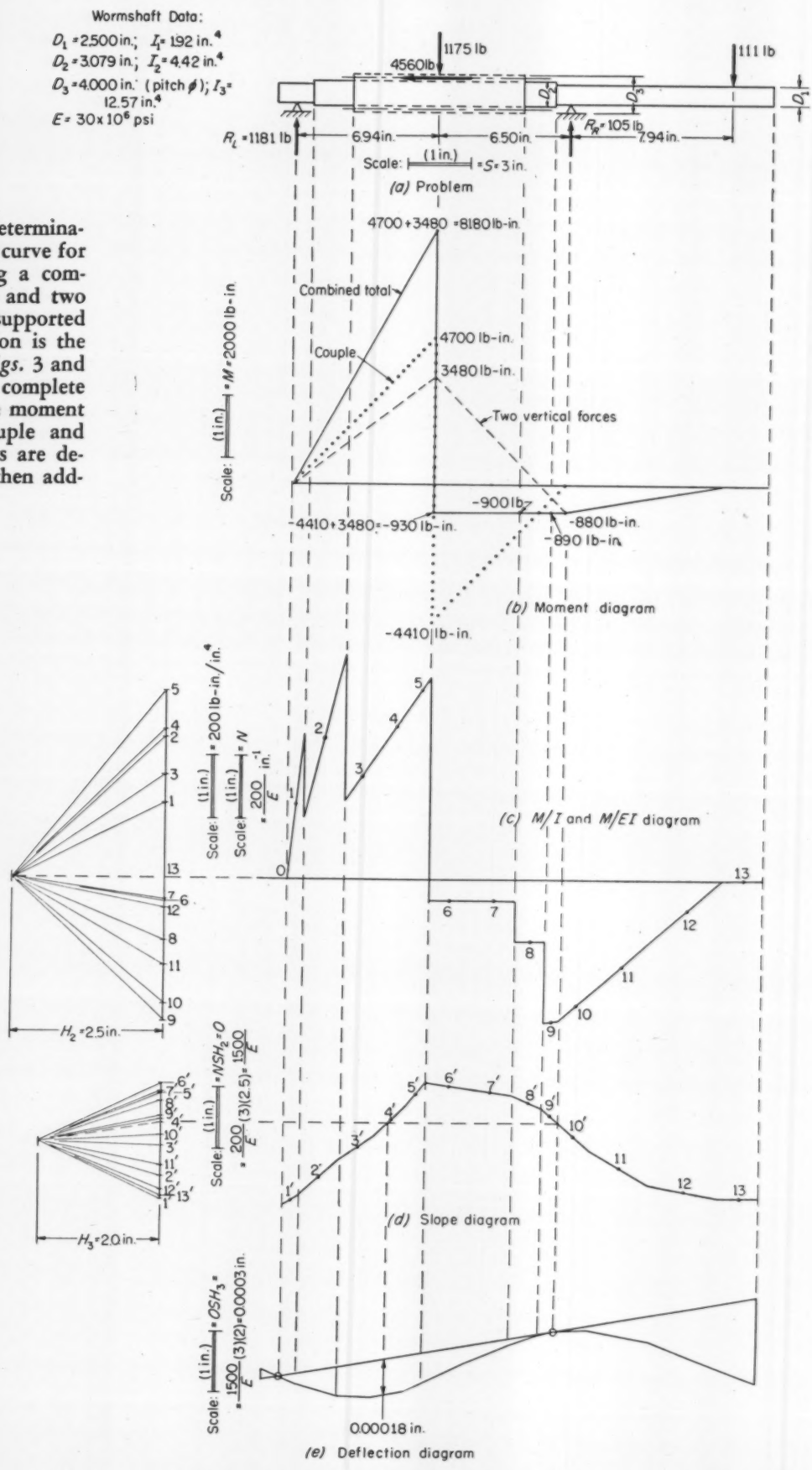

Wormshaft Data:
$D_1$ = 2.500 in.; $I_1$ = 1.92 in.$^4$
$D_2$ = 3.079 in.; $I_2$ = 4.42 in.$^4$
$D_3$ = 4.000 in. (pitch ⌀); $I_3$ = 12.57 in.$^4$
$E$ = 30 x 10$^6$ psi
1175 lb
111 lb
4560 lb
$R_L$ = 1181 lb
$R_R$ = 105 lb
6.94 in.
6.50 in.
7.94 in.
Scale: (1 in.) = S = 3 in.
(a) Problem
4700 + 3480 = 8180 lb-in.
Combined total
Couple
4700 lb-in.
3480 lb-in.
Two vertical forces
Scale: (1 in.) = M = 2000 lb-in.
-900 lb
-4410 + 3480 = -930 lb-in.
-880 lb-in.
-890 lb-in.
(b) Moment diagram
-4410 lb-in.
Scale: (1 in.) = 200 lb-in./in.$^4$
Scale: (1 in.) = $\frac{200}{E}$ in.$^{-1}$ = N
(c) M/I and M/EI diagram
$H_2$ = 2.5 in.
Scale: (1 in.) = $\frac{200}{E}$(3)(2.5) = $\frac{1500}{E}$ = NSH$_2$ = O
$H_3$ = 2.0 in.
(d) Slope diagram
Scale: (1 in.) = $\frac{1500}{E}$(3)(2) = 0.0003 in. = OSH$_3$
0.00018 in.
(e) Deflection diagram

Fig. 5—Graphical determination of the deflection curve for a worm shaft having a combination of a couple and two concentrated loads supported at two points. Solution is the same as applied in *Figs.* 3 and 4. To obtain the complete moment diagram, the moment diagram for the couple and for the vertical forces are determined separately, then added algebraically.

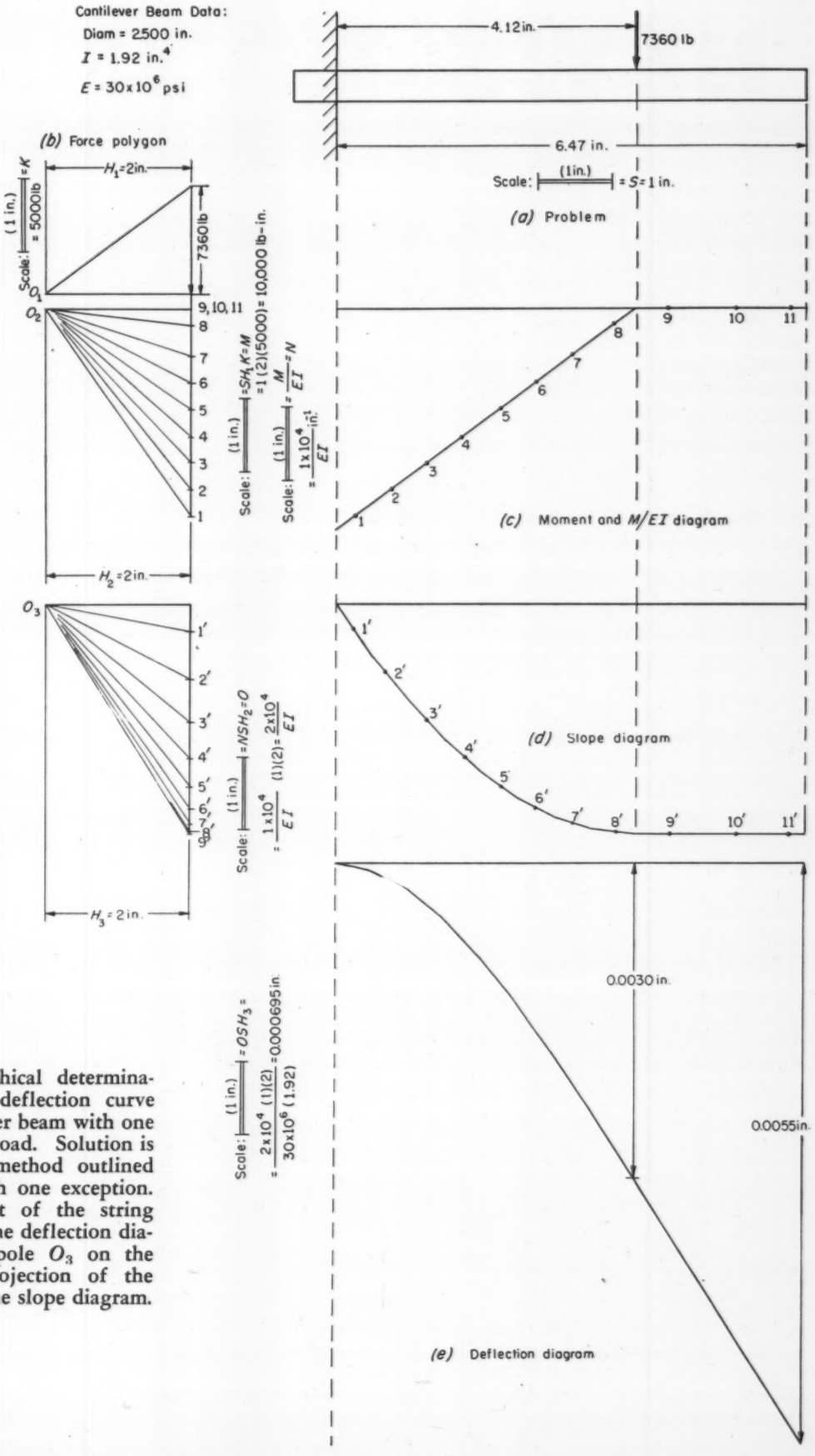



Fig. 6—Graphical determination of the deflection curve for a cantilever beam with one concentrated load. Solution is identical to method outlined in *Fig.* 3 with one exception. In the layout of the string polygon for the deflection diagram, place pole $O_3$ on the horizontal projection of the base line of the slope diagram.

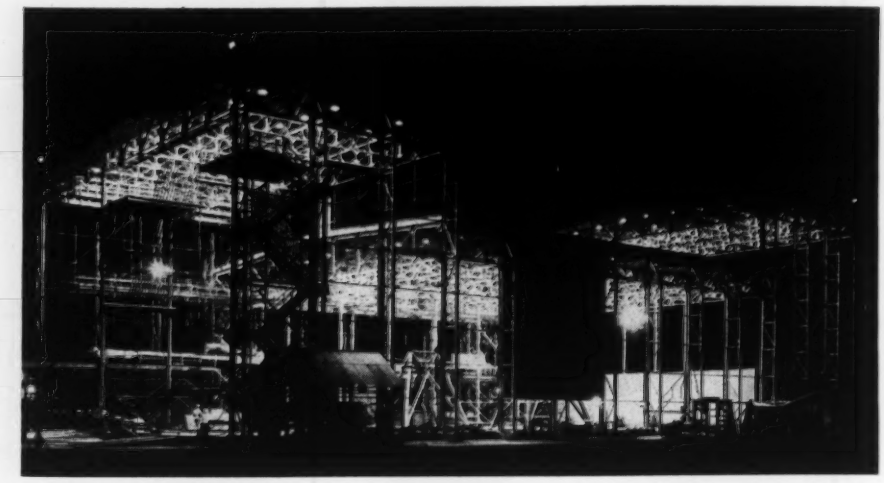
# Engineering NEWS ROUNDUP

## New Test Facility is Largest in Aircraft Industry

Constructed especially for testing structural features of Navy flying boats, Convair's huge steel dock now in operation at San Diego, is the largest facility of its kind in the aircraft industry.

Maximum height of the static test facility is 67 feet, with ceiling heights of 56 feet in one bay and 35 feet in another. Approximately 2200 cubic yards of concrete and 60 tons of structural steel were required to build the three-foot concrete foundation of the 100 by 196 foot test chamber. Test recording equipment is installed in a separate building which includes offices for the engineering personnel.

Components placed in the structure will be destroyed during the tests for ultimate strength characteristics in new planes. Various types of loads can be applied by hydraulic jacks on an airplane. The equipment can simulate many flight conditions such as rolling-pullout, positive low angle of attack, symmetrical hull loading and dynamic loading. Equipment can apply loads ranging from 60,000 to 1 million pounds from any direction and can divide any one load into as many as 200 application points.

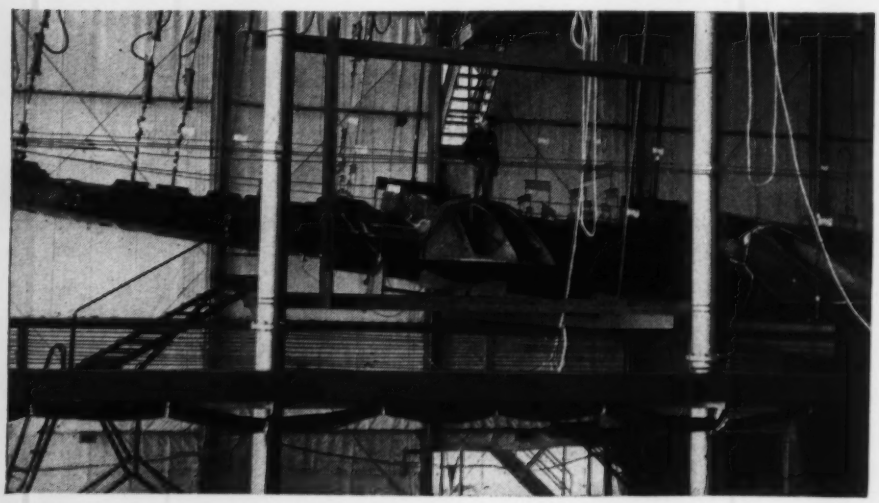


Night view outlines the huge steel skeleton of the test facility, entirely enclosed in plastiglass siding for weather protection

On the R3Y wing recently tested, 3000 sponge rubber pads, 5 by 5 inches were glued to the wing surface. These pads, plus a "whiffletree" arrangement which distributes the load applied by hydraulic ram, make it possible to duplicate accurately every flying or landing condition load that an airplane is likely to encounter.

Future tests will include an R3Y pressurized hull, which will be bent, twisted and subjected to 11 different loading tests in a simulated flight at 30,000 foot altitude.

A wing under load is shown being tested in Convair's new static test facility. Catwalks above facilitate access to test apparatus. Below are hydraulic lines and hundreds of wires connected to strain gages



## Electric Motors Rerated by NEMA

New standards allowing more horsepower to a particular frame size for all of the popular high-production alternating current electric motors from 1 to 30 horsepower were announced recently by the National Electrical Manufacturers Association. The advent of superior insulating materials, new and better silicon steels and improved techniques, as well as advances in motor design, permit packing more horsepower in a given space. The new standard permits a 30 horsepower motor to be

# LOOKING AHEAD TO ECONOMIES IN PRODUCTION?

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JOHNSON BRONZE CO., 525 South Mill St., New Castle, Pa.

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*Sleeve-Type*

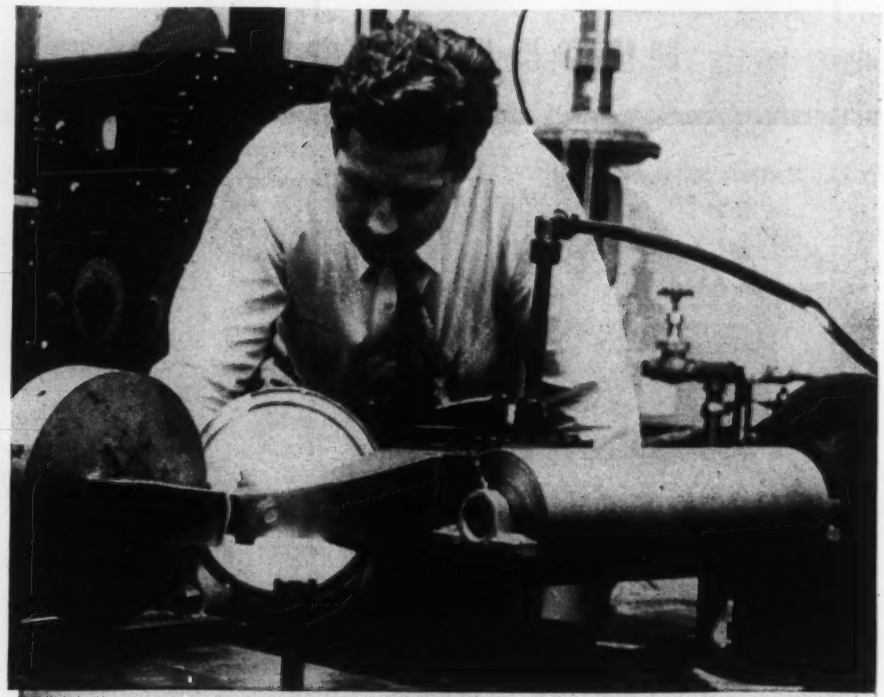
**SLEEVE BEARING HEADQUARTERS SINCE 1901**

constructed to the same size as a 15 horsepower motor was previously.

Motors conforming to the new standards will continue to meet the same performance standards of torque, temperature rise and starting current limitation as before. The frame numbering system also remains the same although motors from 1 to 30 horsepower can now be constructed using the same number of frames previously required for the 1 to 15 horsepower range.

## Ten Pound Motor Develops 25 Horsepower

Said to be little larger than a rolled up newspaper, an expendable electric motor helps guide Navy torpedoes on a true course. Working life of the motor is only one-fifth of a second, the time necessary to impart a velocity of 13,000 rpm to the flywheel of the torpedo's directional gyroscope. A development of Westinghouse Electric Co., the motor is 3½ inches in diameter and 10 inches long.



BUCKET BLASTER: Scalding blasts of air timed by the slotted wheel at right, set up violent vibrations in the gas turbine bucket seen protruding from the drum-shaped metal support at left to simulate service conditions in a modern gas turbine. Precise timing of the air blasts sets up destructive vibration in the bucket and produces fatigue failures in a matter of minutes. Details of the reaction of the bucket can be studied by stroboscopic light and strains are recorded while the test is in progress. The machine was developed by a GE laboratory scientist

SMALL GAS TURBINE: Weighing less than 100 pounds and about two cubic feet in volume, this gas turbine delivers 50 horsepower at 40,000 rpm. Labelled the Mars by the manufacturer, Solar Aircraft Co., it will run on a variety of fuels from diesel oil to high octane gasoline

## Electronic Computers Beget New Mathematical Techniques

A new science of computation, designed for use with modern high-speed electronic computers, is taking form. Based on a combination of the older hand-machine computing techniques with the results of new mathematical theories and methods of analysis, the new science of numerical analysis is providing a reservoir of mathematical knowledge that can be drawn on for innumerable applications by users of large-scale automatic computers.

According to recent announcements of the National Bureau of Standards' Institute for Numerical Analysis, (INA) these new mathematical techniques are being used to translate problems from equation form into a form involving operations that the available computer can perform. Major emphasis thus far has been placed on techniques for the solution of simultaneous equations, inversion of matrices and determination of their characteristic values and methods of integrating partial differential equations, topics important in the solution of problems in aerodynamics and other branches of engineering research.

Research and development in numerical analysis—the branch of mathematics dealing with numerical calculations—requires intensive theoretical study based on a broad background of pure mathematics. However, before the advent of modern high-speed computing machines, numerical analysis was unfashionable among professional mathematicians, and its development had lagged far behind other mathematical disciplines. To conduct the theoretical and applied

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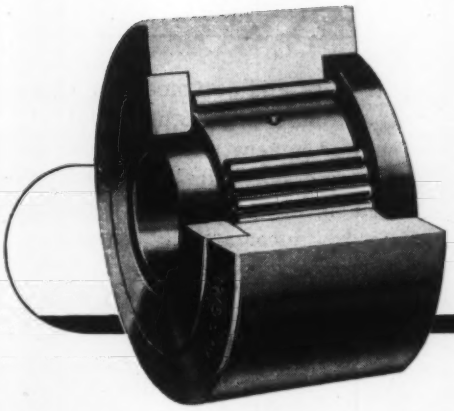


# How to increase the versatility of cam follower applications

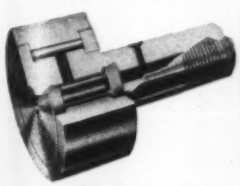
The ever increasing number of cam action applications in modern machinery is partially responsible for insuring greater efficiency and productivity through increased automatic operation. Helping to make this possible is the availability of a precision means of converting motion originating through cam action to adjacent mechanisms with an adequate anti-friction cam follower bearing.

The first such bearing acceptable to machine builders was produced by McGill and is now used extensively in all types of automatic machinery. The MULTIROL Cam Follower design requires mounting by means of securing the stud, leaving the anti-friction roller free to follow the cam.

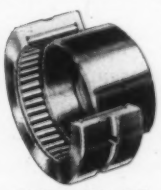
Another more recent McGill development in cam follower design is the MULTIROL CYR series bearing that uses an inner race rather than the conventional stud. The bearing is sealed with roller retaining end plates tightly fitted and secured to the shoulders of the inner ring. Yoke mounting is possible where desirable with the CYR bearing on shaft sizes ranging from ¼" to 1¼" for corresponding roller diameters of ¾" to 4".

The CYR series bearing is non-separable with a thick outer race section to withstand the heavy shock load encountered on all types of cam applications found on automatic machinery. This heavy duty bearing is not only suitable to direct cam action over a wide speed range but it can be applied as a means to control motion of machine parts that require guide or support rollers. Examples include lathe or planer beds, welding machine heads, aircraft wing flaps, wire straightening rollers, etc.

## Other McGILL® Bearings



MULTIROL CF

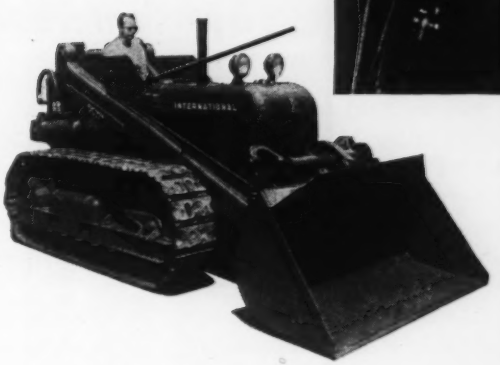


MULTIROL SE

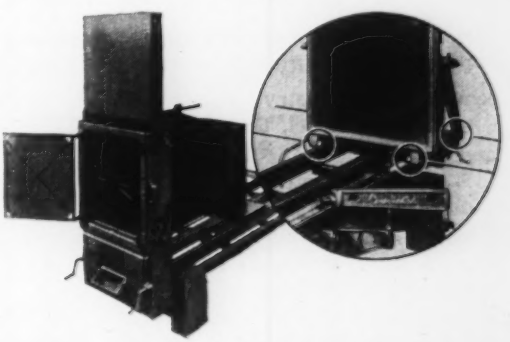
GUIDEROL

A new 140 page Bearing Reference Guide complete with 30 pages of vital engineering data has just been released by the McGill Manufacturing Company. It has the full story on the advantages of MULTIROL CYR Bearings as well as information on MULTIROL CF and SE and GUIDEROL Bearings. Send now for your copy of McGill Catalog No. 52.

## Typical Performance



Bucyrus-Erie Company, South Milwaukee, Wisconsin uses MULTIROL CYR series bearings as quadrant rollers on the operating lever that controls the bucket on their TD-9 one yard Dozer-Shovel. These bearings allow easy and free lever motion as they ride the quadrant cam in one of four positioning pockets. McGill GUIDEROL bearings are used in the PVT hydraulic unit on this same Dozer-Shovel.



Typical of the varied uses MULTIROL CYR bearings can satisfy are the track rollers on the highly precision Process Copy Cameras built by Consolidated Hammer Dry Plate and Film Company of Chicago, Illinois. Here four CYR bearings support and guide the copy board along rails before the camera. These bearings permit free and accurate adjustments for sensitive camera focus.

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investigations in this field that are necessary in order to fully utilize the postwar developments in automatic computing, INA was established early in 1948 as part of the Bureau's program in applied mathematics and computing machine development. The INA now has a permanent staff of about 70, supplemented by visiting scholars from universities and other research organizations who are permitted to use the facilities of the Institute.

## Packaged System Monitors Nuclear Reactors

The first "packaged automatic control system to electronically monitor the operation of atomic piles and their related processes" has been successfully designed. A completely integrated control unit, the system will include a multiplicity of electronic instruments—amplifiers, servo-amplifiers, recorders, controllers and servomotors. These will automatically regulate the rate of power generation of nuclear reactors (atomic piles) at predetermined levels. Essentially this is done by automatically regulating the reactor's control rods, which are analogous to an automobile throttle.

Control systems for atomic piles have previously been designed by the Atomic Energy Commission. It purchased the control instruments

## First Conference on Mechanisms

The First Conference on Mechanisms will be held on October 12-13, 1953, in the Memorial Union Bldg. on the campus of Purdue University at West Lafayette, Indiana. Purpose of the Conference is to better acquaint designers and other engineering personnel with the capabilities and applications of mechanisms in automatic machinery as well as design of mechanisms for such applications. Joint sponsors of the Conference are the Mechanical Engineering Dept. of Purdue University and the Editors of MACHINE DESIGN.

Advance registration is advisable and may be made with the special postcard opposite page 176 in this issue.

Fee for the Conference is $20 per person which may be paid in advance or at the time of registration. All checks accompanying advance registrations should be made payable to Purdue University and mailed to Mechanisms Conference, Comptroller's Office, T.E.D., Purdue University, West Lafayette, Indiana. The banquet on Monday, October 12 is included in the reservation fee. Overnight accommodations are not included in the fee, and should be reserved at the Union Club on the campus or the Fowler Hotel, Lafayette, Indiana, as soon as possible. Rates are from $3.50 single, $4.50 double and $6.00 twin at the Union Club.

### Program—First Conference on Mechanisms

**Session 1—Mechanisms Today**
(Morning—October 12)

Welcome
George Hawkins, Dean, Schools of Engineering, Purdue University

Mechanisms in Industry
Colin Carmichael, Editor, MACHINE DESIGN

Plans and Purposes of The Conference
E. S. Ault, Professor of Machine Design, Purdue University

Mechanisms and Their Classification
A. S. Hall, Professor of Mechanical Engineering, Purdue University

**Session 2—Mechanism Problems with High-Speeds**
(Afternoon—October 12)

Recognition and Treatment of Acceleration
A. Holowenko, Assoc. Professor, Mech. Engrg., Purdue University

Design and Application of Noncircular Gears
H. E. Peyrebrune, Vice Pres., Eng., Miehle Printing Press & Mfg. Co.

Utilizing Irregular Gears for Inertia Control
W. W. Sloane, Vice Pres., Eng., Goodman Mfg. Co.

**Conference Banquet**
(Evening—October 12)

Toastmaster: Colin Carmichael, Editor, MACHINE DESIGN

Speaker: Dr. M. B. Ogle, Head, Dept. of History and Government, Purdue University

**Session 3—Procedures in Mechanism Design**
(Morning—October 13)

A Simplified Approach to Linkage Design
E. W. Pike, T. R. Silverberg, P. T. Nickson, Equipment Engineering Div., Raytheon Mfg. Co.

Designing Cams with the Aid of Computers
R. F. Griffin, Research Eng., Warner & Swasey Co.

**Session 4—Applications of Mechanisms in Automatic Machinery**
(Afternoon—October 13)

A Systematic Method of Correlating Motions
J. Longstreet, Chief Textile Eng., Warner & Swasey Co.

Round Table Discussion with Authors
Chairman: Roger W. Bolz, Associate Editor, MACHINE DESIGN

(Advertisement)

# Facts about *HELI-COIL* inserts you should know

*What they are*

*Heli-Coil** screw thread inserts are precision formed coils of stainless steel or phosphor bronze wire. Wound into tapped holes, they form permanent, non-corrosive, strip-proof threads of astonishing strength. Available for National Coarse, National Fine and Unified threads, pipe threads and spark plug threads. They are made in all standard sizes and lengths for assemblies requiring Class 3, 3B, 2 or 2B fits.

*What they are for*

AS ORIGINAL COMPONENTS: *Heli-Coil* inserts are used to provide stronger, lighter fastenings, corrosion-proof, wear-proof threads in all assemblies.

FOR PRODUCTION SALVAGE: When conventional tapped holes are damaged in production, restore them on the line with *Heli-Coil* inserts. Get better-than-original strength with no increase in screw size and no tell-tale signs of rework.

FOR SPEEDY REPAIRS: When tapped threads wear, strip or corrode in service, renew them in minutes on location in shop or field with *Heli-Coil* inserts. No welding—no plugging—no secondary machining—no oversize screws.

*How they work*

Holes are drilled and tapped as you do for ordinary threads—then *Heli-Coil* inserts are wound into tapped holes by hand or power tools. Install in a few seconds, assure thread protection forever. Can be used in any metal wood or plastic.

*No other method is so simple, effective and practical.*

*What they do for you*

*Heli-Coil* inserts *save money* because they strengthen threads and make *fewer* smaller fastenings do the same holding job. They make *lighter* bosses and flanges practical and they *save weight* in two ways: (1) by permitting use of cap screws, instead of bolts and nuts; (2) by allowing use of smaller, shorter, fewer cap screws. *Heli-Coil* inserts *protect* your product from thread wear, galling and stripping for life in every kind of metal, in plastics or wood. They preserve customer good-will by preventing product failure, due to thread fault. *Heli-Coil* inserts improve the end product, cut rejects, salvage threading errors.

Best time to put *Heli-Coil* inserts benefits to your use is right at the designing board, as many leading manufacturers are doing. But to convince you of their many advantages ask for a working demonstration right on your production line. Write today! Complete information and engineering data is available in the *Heli-Coil* catalog. Use Coupon!

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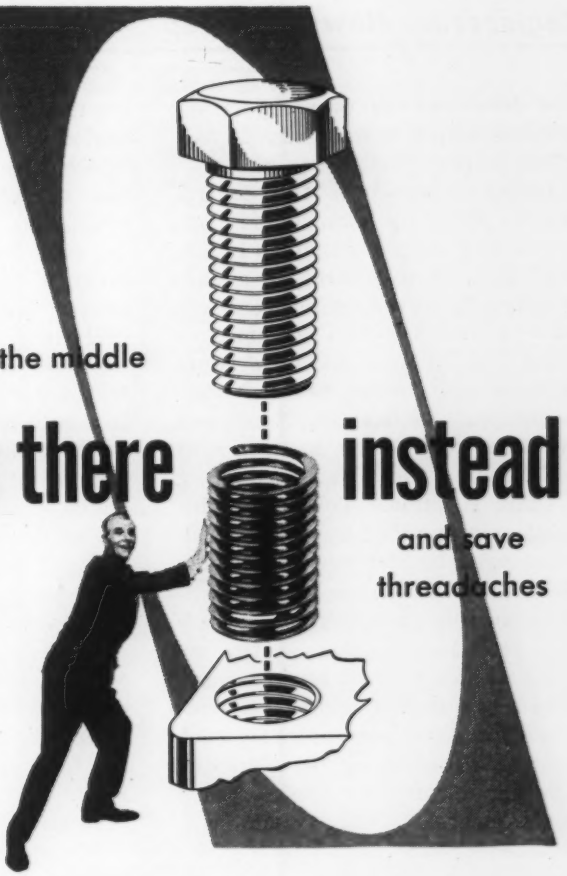
***Approved for All Military and Industrial Uses***

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You can be a hero to both sales management *and* production management by telling them about *Heli-Coil** Screw Thread Inserts.

These precision formed inserts of stainless steel or phosphor bronze wire make vastly stronger threads in metal, plastics, and other materials. So much stronger that you can safely use smaller and fewer and shorter cap screws—thinner sections, lighter bosses. Thus costs are reduced, production simplified. And threads cannot strip, corrode or gall—they never wear out.

Learn how other designers are using *Heli-Coil* Screw Thread Inserts. Get the technical data you need to apply them to your "threadaches." Use the coupon—now!

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and developed its own regulating systems which varied from installation to installation.

Initial function of the control system, made by Minneapolis Honeywell Regulator Company's Industrial Div., is to guarantee a safe "start-up" of the chain reaction. This chain reaction commences when the nucleus of a uranium atom is split under neutron bombardment. As it splits, it releases more neutrons which, in turn, split additional nuclei, thus producing a chain reaction. To sustain this reaction a specified number of neutrons must be liberated per second.

As the control rods are removed to begin this chain reaction, a neutron-sensitive detector in the reactor itself sends out tiny "pulses." These are picked up by an electronic amplifier—one pulse for each neutron detected by the chamber. Another electronic device counts these pulses, totaling them on a digital register. The operator, by determining the number of pulses occurring per second (or any given period of time) knows the rate at which the reaction is increasing and adjusts the control rods accordingly. As the reaction increases, still another electronic instrument, a counting rate meter, integrates these pulses, translating them into voltage readings proportional to the number of pulses detected per second. The overall effect is to provide the operator with an automatic means of sensitively regulating the early stages of the chain reaction.

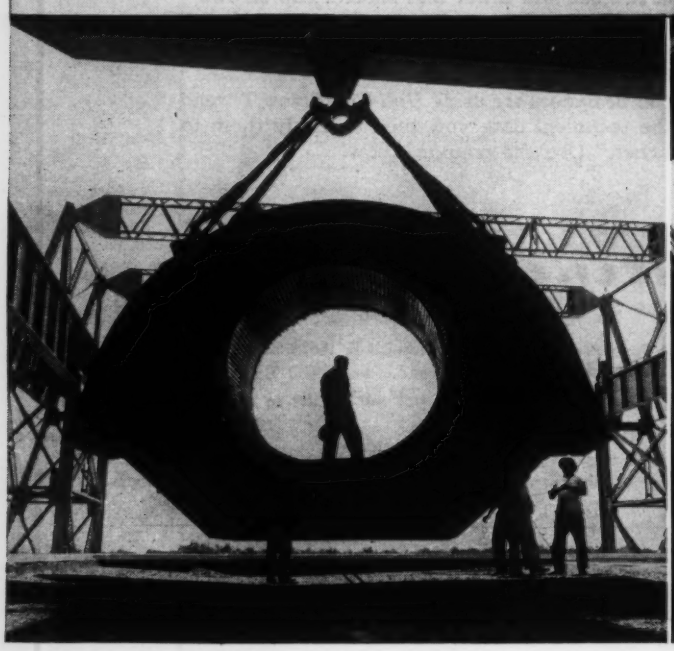
During this entire start-up process, and after the proper operating level has been reached, other electronic units in the control system are continually monitoring the reaction. For example, one series of electronic amplifiers and recording instruments monitors the reaction for too rapid a rise in the power level. If the units detect any abnormality they immediately shut down the reactor. Another series of amplifiers acts to prevent the power level from going too high. Should this occur they also will immediately shut down the reactor.

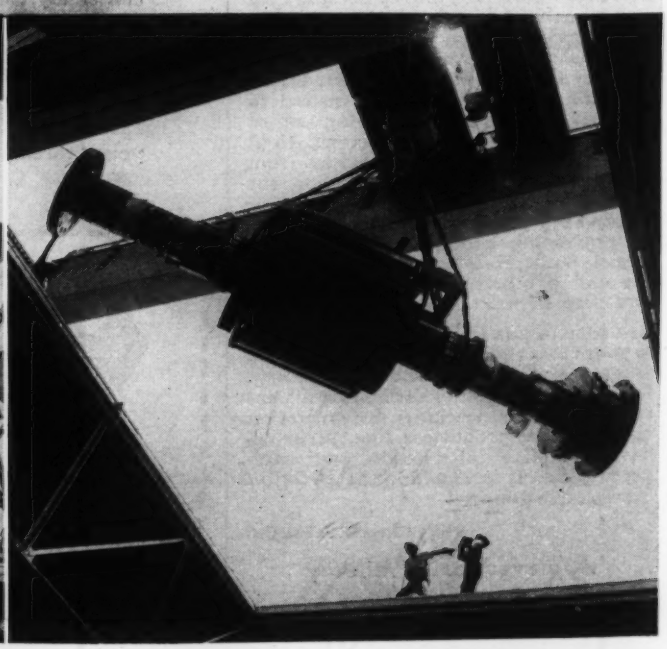
Once the reactor is safely started and at the desired operating level, a final control series takes over to regulate the chain reaction continuously at previously determined levels. To accomplish this, a specially developed instrument called an electrometer records the power level, signalling servo-amplifier units. These units, linked to special servomotor equipment, automatically adjust the control rods to regulate the nuclear reaction.

## Pressure Vessel Tests Sub Signal System

A large pressure vessel has been used to provide hydrostatic pressure comparable to or even greater than that exerted upon a submarine at maximum operating depth. For testing performance of a submarine signal ordinarily ejected from a sub far below the surface

MOST POWERFUL MOTOR: Stator, left, and rotor, right, of the most powerful electric motor ever built are shown being installed at the USAF Arnold Engineering Development Center. Developing 83,000 horsepower, the motor is one of two being built by Westinghouse. The two 83,000-horsepower motors with two 25,000-horsepower motors will provide 216,000-horsepower to drive air at transonic and supersonic speeds through wind tunnels at the development center





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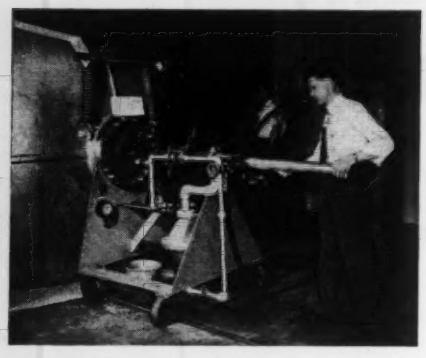
. . . because you'll find all the right answers in a Hyatt catalog. Hyatt's complete line of cylindrical roller bearings—more than 800 sizes in the Hy-Load series alone—makes your job easier, because it makes possible greater design flexibility. And in addition, when you specify Hyatt bearings you know you're getting the very best! If your file of Hyatt catalogs is incomplete, contact one of Hyatt's sales-engineers—or write to Hyatt Bearings Division, General Motors Corporation, Harrison, New Jersey.

# HYATT ROLLER BEARINGS



of the sea and developed by the Naval Ordnance Laboratories, the method eliminates the use of submarine and crew for extended test periods and provides a quick, accurately controllable means for testing.

Signals are actually launched into the pressure vessel. Velocity attained by the signal in rising from the sub to the ocean's surface is simulated by decreasing vessel pressure at a rate comparable to the change in ocean water pressure.

---

**Thirty-seven tons of batteries** power a new coal hauling unit consisting of two 20-ton locomotives and two power cars housing the batteries. Less than 4 feet high, the unit is over 100 feet long. Batteries, developed by Gould-National Batteries Inc. for the job, are 240-volt 2,668 ampere-hour units of the 6 hour discharge rate. Locomotives. made by Jeffrey Mfg. Co., will operate a full 8 hour shift on one charging.

## AMA Sponsors Management Seminars

More than 2000 executives will participate in the 20-week fall program of seminars conducted by the American Management Association. "Management of the Engineering Function," "Getting the Maximum Benefit from the Product Research and Development Department," "Practical Progress Toward Automation," and "The Organization of the Quality Control Function," are seminars of particular interest for engineers.

Seminars scheduled are of two types: workshop seminars, discussion groups of 15 exchanging information and experience; and orientation seminars, limited to 30, for instruction, practice or review in a particular subject. The orientation seminar was developed this year to provide short meetings for "refresher" purposes plus a picture of the latest developments.

Previous leaders have included Lloyd A. Hatch, Vice-President, Research & Product Development, Minnesota Mining & Mfg. Co.; Walter B. Schaffir, Product Engineer (Administrative), Sperry Gyroscope Co. Div.; Roderic M. Scott, Director of Engineering, Perkin-Elmer Corp.; Willis M. Cooper, Chief Engineer, Engineering Department, Organic Chemicals Div., Monsanto Chemical Co.; Harold Engstrom, Manager of Industrial Engineering, Sylvania Electric Products Inc.; and Dorian Shainin, Chief Engineer, Rath & Strong.

From August 10, 1953 through January 27, 1954, 130 seminars dealing with 86 specific problems will be held. In the three years since the first AMA seminars met, they have grown to an organized program involving 4000 executives annually. Additional information and copies of the seminar announcement may be obtained from the Seminar Registrar, American Management Association, 330 West 42nd St., New York 36, N. Y.

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**Plastic tanks** for fresh water and oil storage are being installed on U. S. Navy minesweepers to conduct service tests. Development of the fiber glass reinforced tanks has been speeded due to shortages of monel and aluminum bronze now used. In addition to weighing 30 to 40 per cent less than metal tanks, the plastic tanks are corrosion resistant and nonmagnetic. Sizes will range from 100 to 1687 gallons.

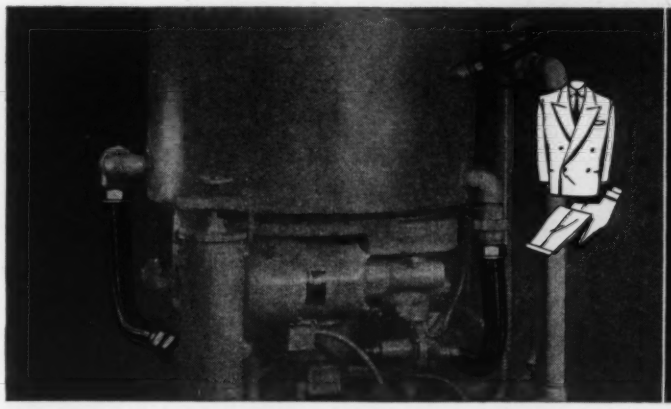
## First Titanium Lab

The first industrial laboratory in the U. S. to be devoted exclusively to research and development on titanium was formally opened at Niles, Ohio, recently. Basic research, development of titanium and titanium alloys and production testing will be carried out at the lab by Mallory-Sharon Titanium Corp., owned jointly by P. R. Mallory & Co. Inc. and Sharon Steel Corp.

In addition to normal laboratory equipment, metallographic and spectrographic equipment, mills

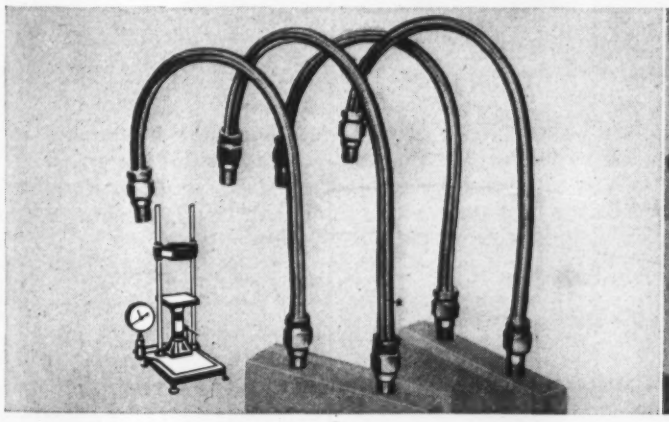
ANTISUB 'COPTER: Developed for antisubmarine service, the Bell XHSL-1 combines compactness and high rotor tip speed and loading to produce high cruising speed and range

# Pick an idea—lick a design problem...

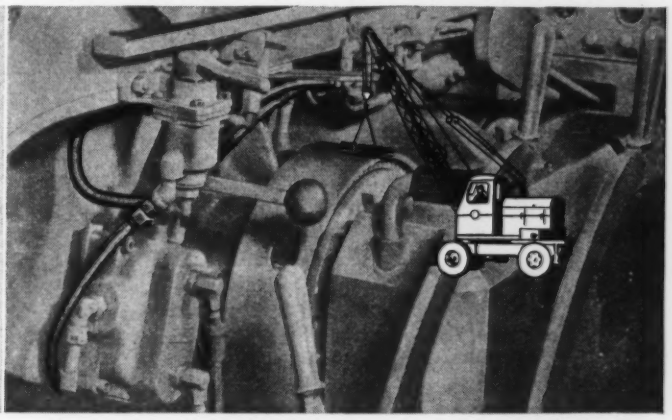


***END VIBRATION AND LEAKAGE.*** Titeflex® metal hose, used as fill and drain lines of SEC Synthetic Cleaning Units, kills vibration and prevents solvent leakage at fittings. Tough, wear-and-corrosion-resistant Titeflex is just as effective in handling steam, oil, lubricants, fuels, gases, brine, acids, compressed air or oxygen. Design and construction of Titeflex assure trouble-free performance. Excellent for projects involving extreme configurations.

***CONTROL CRITICAL PRESSURES.*** How would you connect 280 cylinders of fire-extinguishing carbon dioxide at 850 psi to line? Walter Kidde & Company licked this problem with Titeflex flexible metal hose which met all insurance standards and withstood rigid application requirements. Titeflex also conveys hundreds of different fluids under as many different temperature and pressure conditions. Resists corrosion, vibration, physical abuse.



***CONDUCT STEAM SAFELY.*** Plates for Carver Laboratory Press carry steam up to 200 psi (nearly 400°F.) for heating—water for cooling. The connections are flexible, pressure-safe Titeflex. Braiding gives extra strength. Added problems of vibration, pulsation, continuous movement, corrosion or abrasion make Titeflex invaluable in scores of other applications.



***FIGHT FATIGUE AND WEAR.*** Titeflex metal hose eliminated maintenance on air control lines of Unit Mobile Cranes. All-metal construction, with braiding woven directly upon the hose, provides great strength and resistance to vibration, corrosion, wear and abuse. Flexibility of Titeflex permits simplified assembly even where space configurations are problems.

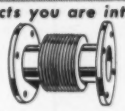
***THE USES FOR TITEFLEX®*** seamed flexible metal hose and Uniflex seamless flexible metal hose are limited only by engineering ingenuity. And Titeflex design engineers—working *with* customers—develop new applications daily. Somewhere in your plant or on your products Titeflex can improve operation and maintenance—or simplify a design problem. Our *new 48-page Metal Hose Catalog* No. 200 shows you how and why. To get your free copy, simply mail the coupon.

## Let Our Family of Products Help Yours

**Titeflex**

*✓ Check products you are interested in.*

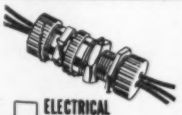
☐ SEAMED AND SEAMLESS METAL HOSE



☐ PRECISION BELLOWS

☐ IGNITION HARNESS

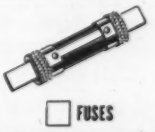
☐ IGNITION SHIELDING



☐ ELECTRICAL CONNECTORS

☐ RIGID AND FLEXIBLE WAVE GUIDES

☐ WIRING SYSTEMS



☐ FUSES

TITEFLEX, INC.
508 Frelinghuysen Ave.
Newark 5, N.J.

MAIL COUPON TODAY

Please send me without cost information about the products checked at the left.

NAME_____

TITLE_____

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for hot rolling test specimens, heat treating and melting furnaces and an X-ray diffraction unit have been installed.

Other facilities of the company at Niles are a complete melting shop and the Niles Rolling Mill, a division of Sharon Steel Corp. Titanium and titanium alloy sheet strip plate and other flat rolled products, as well as rods, hexagonals and forgings are produced.

Research carried on by the firm has already resulted in an improved melting process which is said to produce titanium ingots with properties superior to those produced by previous processes. In addition, the yield of metallic titanium from the titanium sponge material is increased.

## ASTM Approves 63 New Standards

At the 1953 Annual Meeting of the American Society for Testing Materials, held in June and July, 63 new specifications and tests were approved and revisions in 185 existing tentatives and standards were acted upon. All the new and revised standards will be published later in the 1953 Supplement to the Book of ASTM Standards.

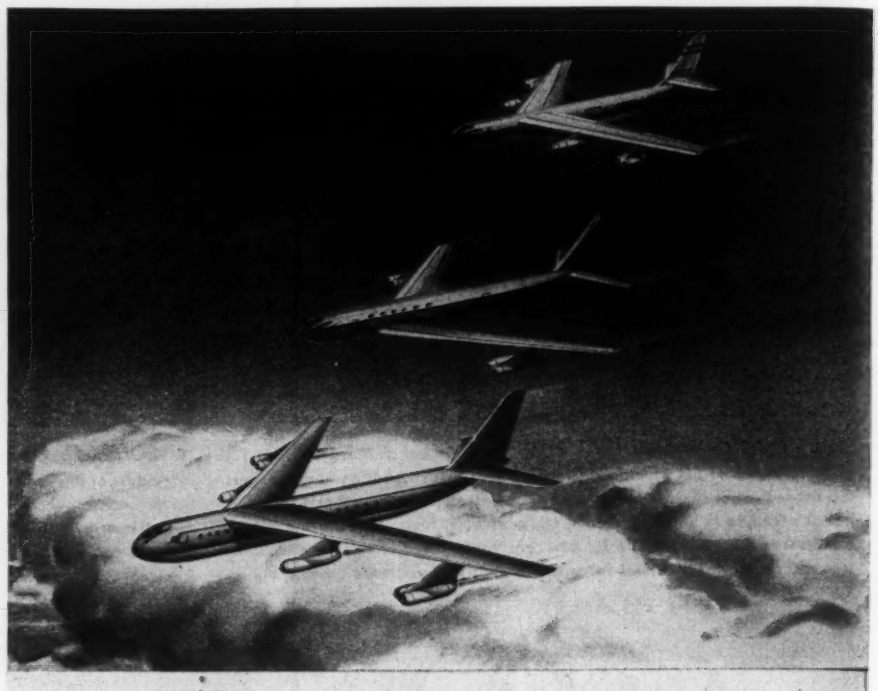
## Record Isotope Charge Used In Inspection of Reactor

The largest single industrial collection of radioactive isotopes in the United States—76,000 millicuries of iridium 192—was used recently in the inspection of a reactor at the Eastern States Petroleum Co. refinery in Houston.

Twenty feet high and 5 feet, 6 inches in diameter, the reactor's walls were 2⅜ inch steel plus five inches of concrete and a ⅛-inch chrome-steel liner. The inspection by Isotope Products Inc., took 8 hours and used a single shot of iridium 192—in five ½-inch long capsules.

Film sheets, each cataloged as to its exact position on the tank, were taped around the steel tank. The charge was then loaded into a special camera and lowered on a steel cable into the reactor. After exposure, the films were developed and interpreted by experts.

Each man working on the project was protected by a dosimeter —a device for measuring exposure to radiation. The isotopes are handled in lead "castles" which shield handlers from radioactive rays.



FUTURE JET TRANSPORTS: Design studies made by Boeing Airplane Co. led to this artist's sketch of three possible jet transports of the future. Powered by turbojet engines, speeds of these planes will be in the 500 mph range and planes will be able to operate from present airports

**Research, development and manufacturing** operations for the production of specialized military electronics equipment are in full progress at General Electric's newly-completed military electronics plant in Utica.

Consisting of a steel-frame single story structure, 842 feet long and 352 feet wide with a two-story office and laboratory section 632 feet long and 75 feet wide, the plant contains what is considered to be one of the most complete industrial installations for the supply of electrical power in a wide range of currents, frequencies and voltages.

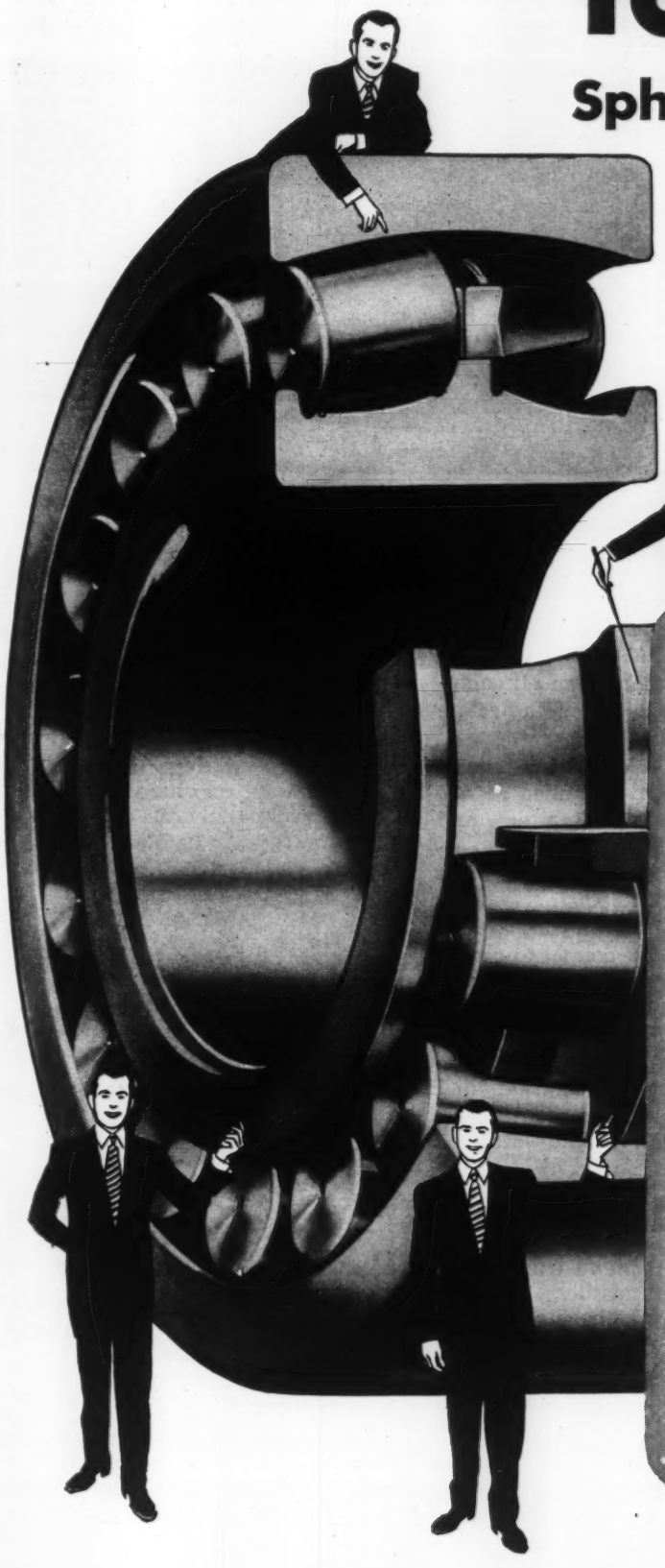
**Recently appointed** Canadian sales representative for American Nickeloid Co., Howard S. Griffin will be in charge of sales for the provinces of Quebec and Ontario.

*"Stupendous—I had all I could do to keep from okaying it!"*

# TORRINGTON

## Spherical Roller Bearings

*offer you these basic advantages!*



- **Accurate geometrical conformity between races and rollers**—for maximum load bearing capacity at all times.
- **Inherent self-aligning feature**—for continuous service and free-rolling even under shock loads and at sustained speeds.
- **All contact surfaces precision ground from the finest of bearing quality steels**—for minimum friction and maximum life under the toughest operating conditions.
- **Races and rollers heat treated according to the most advanced metallurgical procedures**—to insure uniform hardness in all load-bearing parts.
- **Individual one-piece cast-bronze cage for each path of rollers**—to eliminate roller binding and assure freedom of operation.
- **Radial stability provided by land-riding cage and integral flange on inner race**—to give accurate roller guiding.
- **Unit assembly, with sturdy flange and race construction**—for easy, economical handling during installation.
- **Available from stock with either straight or tapered bore**—for shaft or adapter mounting.

*These advantages add up to maximum performance for your bearing dollar. That's why it always pays to specify TORRINGTON Spherical Roller Bearings.*

THE TORRINGTON COMPANY
South Bend 21, Ind. • Torrington, Conn.

**TORRINGTON** SPHERICAL ROLLER **BEARINGS**

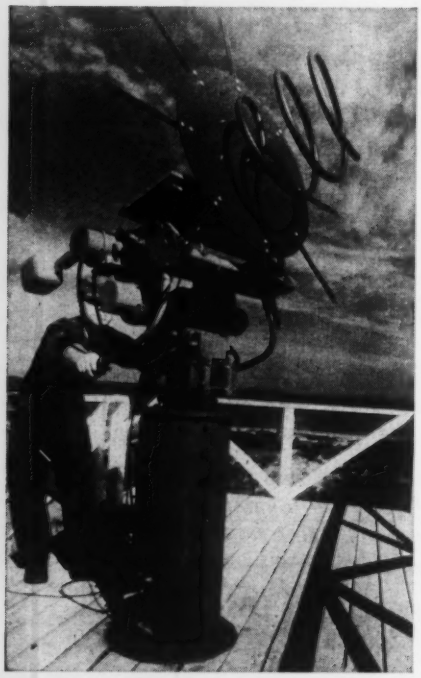
Spherical Roller • Tapered Roller • Cylindrical Roller • Needle • Ball • Needle Rollers

A 1000 mile missile test range over the Atlantic Ocean (left) will permit long range testing of guided missiles such as the Martin Matador (right) when all necessary equipment is installed. Take off of the Matador is speeded by a rocket motor at the tail which falls free when fuel is exhausted

## Missile Test Range

A guided missile traveling at 600 mph or more will cover 100 miles in ten minutes or less. During first flights, to keep missiles such as the Martin B-61 Matador within the limits of the Holloman Air Force Base, New Mexico, flying in circles and figure eights was necessary. The range at the Patrick Air Force Base Missile Test Center near Cocoa, Fla., will permit straight flights of 1000 miles over the Atlantic Ocean when all equipment installations along the range have been made.

Radar and telemetering equipment is presently installed at the Cape, Canaveral, Jupiter and Grand Bahama stations and permits flights in excess of 200 miles to be made. This distance takes the missile a little beyond Grand Bahama at which point radio controls aim the missile for deep water destruction or destroy it in the air. During flights, performance data such as speed, altitude, temperature, fuel consumption and structural stresses are continually transmitted to ground stations from the missile.



Oversize corkscrew is a telemetering antenna. Helical configuration provides good reception

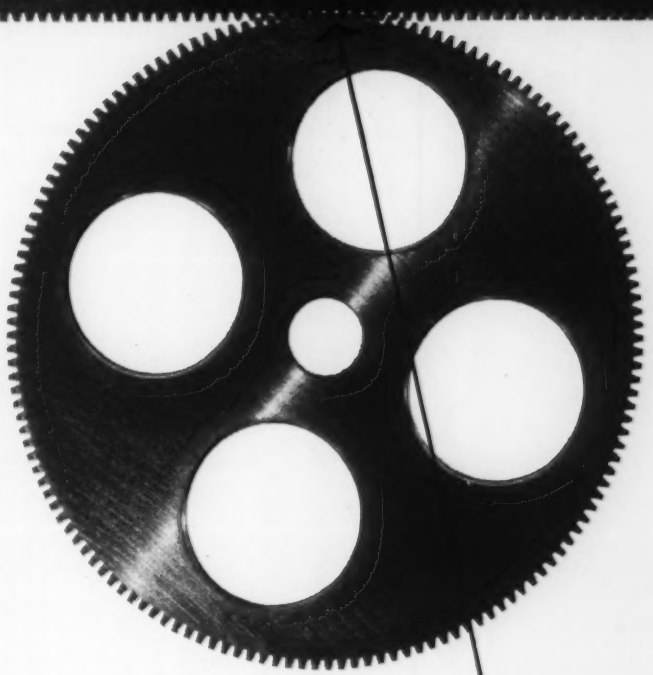
High speed motion picture camera with 40-inch telephoto lens records flight of guided missiles. As many as 30 cameras may be used to film the launching of a missile

VALVE ANALYZER: Sensitivity, adjusting range and capacity of valves, as well as valve seat seal-off, are checked during simulated operating conditions by this valve analyzer at the A-P Controls Corp. laboratory

## Uses for Rare-Earths In Stainless Steel Melting

Rare-earth oxides improve the hot workability of inherently ductile austenitic stainless steels, but do not improve the hot workability of hot-short or hard-to-work grades of austenitic steels, conclude metallurgists of the Carpenter Steel Co. as a result of recent research.

Additions of rare-earth metals and compounds—particularly cerium and lanthanum—in the form of misch-metal produces effects dif-



# *Why* you can *reduce rejection losses* with a Kodak Conju-Gage Gear Checker

## *Why* the composite check

In practice, the final test of gear quality is how the gear works in use. The composite check recommended in American Standard B6.11-1951 shows this conclusively by measuring displacement of the gear when run against a master of known accuracy. And it does it in one quick operation that checks combinations of as many as six types of errors.

## *Why* the Conju-Gage Gear Checker

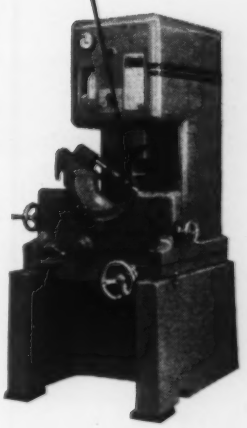
Since displacement represents the sum of both gear error and error in the master, the accuracy of the master used determines the precision of the composite check. The Kodak Conju-Gage Gear Checker uses a master of exceptional accuracy, the Conju-Gage Worm Section. Produced by thread grinding, its accuracy is not limited by the same manufacturing processes which limit accuracy in the gear itself.

To settle for masters of lesser accuracy is to rob yourself of "tenths"—to chance that tolerable error in a gear may coincide with error in the master to cause a needless rejection. Or that intolerable error in a gear may be cancelled by error in the master to pass a gear that will fail in use.

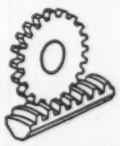
To reject every wrong gear is to guard the quality of your product. To pass every right gear is to reduce such rejection losses to a minimum.

To find out more about how a Kodak Conju-Gage Gear Checker can lower costs while maintaining required precision, send for your copy of the booklet, "Kodak Conju-Gage Gear Testing Principle." Write to

**Special Products Sales Division**
**EASTMAN KODAK COMPANY, Rochester 4, N.Y.**



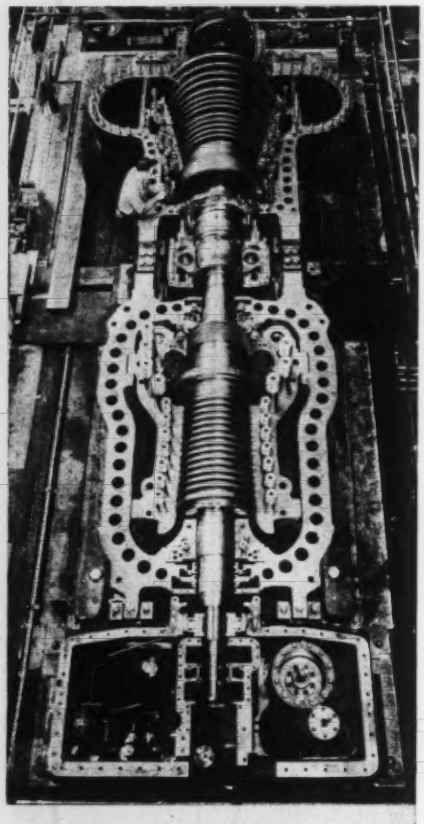
The Kodak Conju-Gage Gear Checker automatically records the composite effects of runout, base pitch error, tooth thickness variations, profile error, lead error, and lateral runout. Illustrated is the Kodak Conju-Gage Gear Checker, Model 8U, for gears up to 8¼" pitch diameter. Smaller models are also available.

**CONJU-GAGE**  **INSTRUMENTATION**

***. . . a new way to check gear precision in action***

*To inspect all kinds of complex parts on a bright screen, Kodak also makes two highly versatile contour projectors.*

Kodak



LARGE TURBINE: Being assembled here for testing are the high and intermediate pressure portions of a 120,000 kilowatt, cross-compound reheat steam turbine. The turbine, manufactured by Allis-Chalmers Mfg. Co., typifies design of units to 250,000 kilowatts and higher

ferent from those caused by rare-earth oxides. Essentially, the difference is that misch-metal additions leave small amounts of cerium and lanthanum in the steel which substantially improve the hot working properties. Rare-earth oxides improve existing working properties while leaving no trace of cerium and lanthanum in the steel.

Misch-metal additions to high-alloyed austenitic stainless steels which are inherently hot-short can transform them into ductile alloys. Smaller additions of misch-metal to low-alloyed austenitic stainless steels have proved beneficial in improving their inherent hot-shortness and in improving fluidity and ingot structure simultaneously.

Cerium fluoride additions have been found to improve the ingot surface and the hot-workability of austenitic stainless steel containing titanium.

---

**Human engineering** as applied to design will be developed under direction of William M. Friedman at the Stanford Research Institute. Former associate director of Walker Art Center in Minneapolis, Mr. Friedman will be staff consultant on design research problems for certain of the Institute's industrial program. In 1952 he conducted a study of the design problems of industry for the West German government.

## Convertiplane Combines Design of Plane and 'Copter

A new type of aircraft, the convertiplane, uses helicopter-type lifting rotors to provide direct lift for take-off, low speed flight and normal or emergency landings.

Three designs are now being developed by Bell Aircraft under USAF contracts. In the first, the unloaded rotor type, the rotor continues to rotate in its normal position during all flight conditions. However, rotor thrust is decreased to zero and rotor rotational speed is reduced to minimize rotor drag and power consumption during high-speed flight. Lift and propulsion in high-speed flight are provided by a fixed wing and propellers or jets.

A tilting rotor system is utilized in the second method. Combination rotor-propellers are mounted near the tips of a fixed wing, operating as conventional rotors during low-speed flight. For high-speed flight, the rotors tilt forward approximately 90 degrees to act as propellers while lift load is transferred from rotors to fixed wings.

In the retractable-rotor type, the third conversion method, the rotor is braked to a stop for high speed flight with lift load transferred to fixed wings. The rotor is then partially or fully retracted to reduce drag. Propulsion in high-speed flight is provided by propellers or jets.

Initial uses for convertiplanes will be military—for reconnaisance, artillery observation, behind-the-lines rescue, transportation and rapid evacuation of wounded. Although the convertiplane is not expected to displace the helicopter, its speed and range performance plus its ability for evasive action are outstanding.

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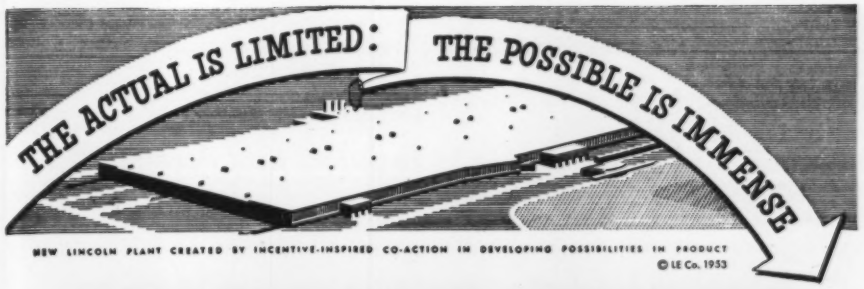
**The Panama Canal** is being overhauled for the first time in 40 years, as part of a ten year plan to enable it to handle more ships. Among the myriad pieces of equipment required for the project is a complete set of 398 motor controls which were shipped from Newark, N. J., in June. All wire insulation and other parts liable to deterioration in tropical atmospheres were specially treated for protection against attack by insects, especially cockroaches and termites, and fungus-proofed by the manufacturer. Federal Electric Products Co.

## Portable Starter Improves Combat Efficiency of Planes

A portable starter unit in the form of a detachable wing container for use on tactical aircraft has been developed by Douglas Aircraft. Under operating procedures, the self-contained gas turbine compressor is ferried by airplane to a forward combat base. There it is disengaged and used as a ground starting cart while the plane, which customarily has a built-in starter, embarks on its mission weighing considerably less or carrying equivalent armament.

Regardless of its base of operations, an aircraft equipped with an engine air starter compressor is assured of unlimited starts for its turbojet or turboprop engine. By cutting a quarter-ton off the plane's weight, the unit improves combat efficiency sufficiently to allow a jet to carry an additional


THE ACTUAL IS LIMITED: THE POSSIBLE IS IMMENSE
NEW LINCOLN PLANT CREATED BY INCENTIVE-INSPIRED CO-ACTION IN DEVELOPING POSSIBILITIES IN PRODUCT
© LE Co. 1953

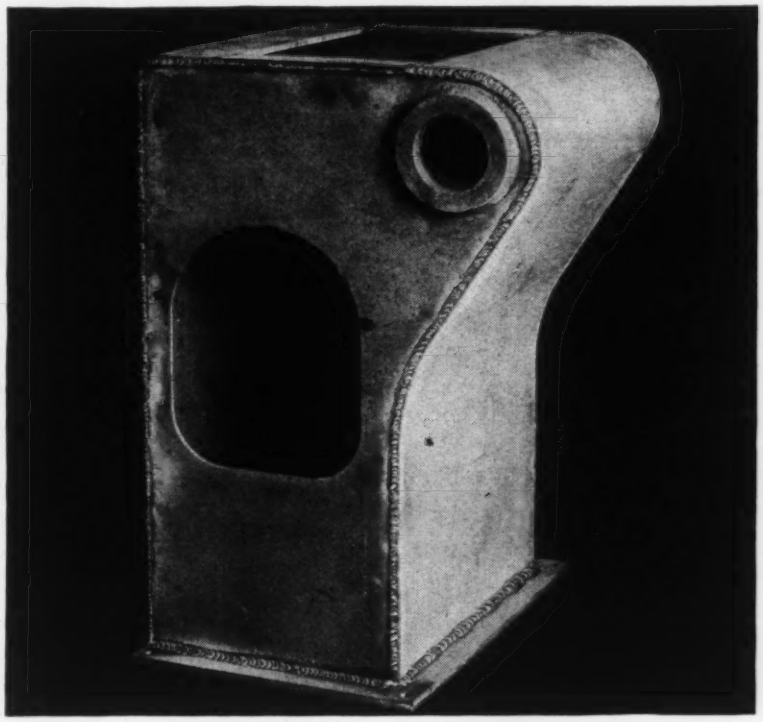


**Fig. 3. Welded steel base** *is made from ⅜", ½" and ⅝" plate. Flame-cut to shape, components are tack welded and then finished welded with fast down hand technique using "Fleetweld 7".*

# WELDED LATHE DESIGNS CUT COSTS: SIMPLIFY PRODUCTION!

BY redesigning lathes for welded steel construction, Divine Bros. Co., Utica, N.Y. has cut excess weight from former cast bases and reduced manufacturing costs 24%. Eliminated investment in patterns.

With the present welded steel construction, less machining is required and costly storage and maintenance of patterns is eliminated, saving production man hours.

Of particular advantage is the shop's ability to alter or modify welded designs at low cost to suit special customer needs. Since pattern changes are no longer involved, production is simpler and deliveries are faster than possible with former cast designs.

**THE LINCOLN ELECTRIC COMPANY**
**Cleveland 17, Ohio**
**THE WORLD'S LARGEST MANUFACTURER OF ARC WELDING EQUIPMENT**

# ALL-WELDED DESIGN REDUCES COSTS CUTS MACHINING TIME

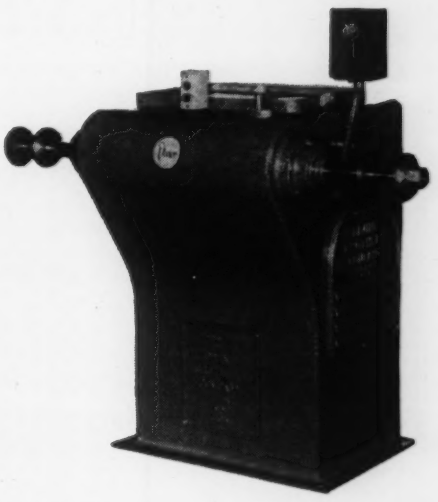


**Fig. 1. All-welded construction** *makes polishing and buffing lathe stronger, more rigid, yet cost of base has been cut from $107 to $86.*

# REDUCES WEIGHT 15% SPEEDS PRODUCTION

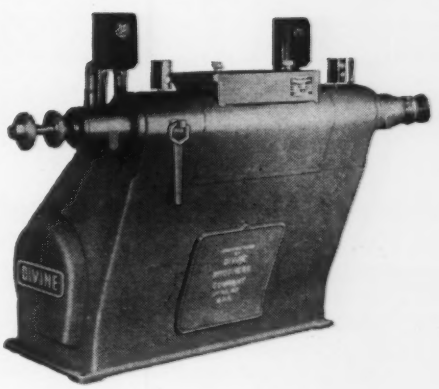


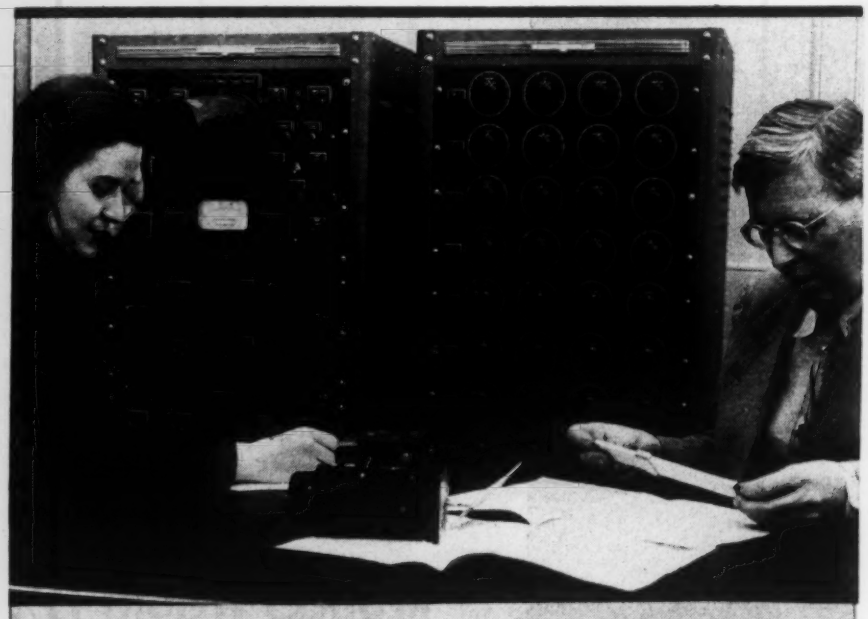

**Fig. 2. Change to welded design** *reduced weight of this lathe 328 pounds! Production no longer held up by delivery of castings.*

**GET THE FACTS!** Latest ideas for speeding conversions from cast iron to welded steel construction are presented in Lincoln Bulletin, "Elements of Weldesign". Available to designers and production engineers by writing on your letterhead to Dept. 1107.

500-pound bomb.

The pneumatic unit contains an AiResearch two-stage centrifugal compressor with a single-stage radial flow turbine. It is self-contained complete with its own electric starter, fuel and lubricating systems. The starter is housed in a tear-drop container which mounts on the bomb racks, its 500 pounds include compressor, battery and fuel tank.

For ground usage, the unit has a swivel nose wheel to which is attached a manual towing handle that actuates a wheel brake when released. Stowage space for the wheels and handle, as well as pneumatic lines, is provided within the container.



HOT BRAIN: Doing two weeks' work in a half hour is simple for this new "brain" designed by General Electric to solve heat problems in small motors for aircraft at the company's Specialty Motor Sub-Department. The instrument, called an electronic thermal analog computer (ETAC), solves one to four-mesh thermal problems involving intermittent duty cycles, forced convection and vapor cooling. It is believed to be the first computer of its kind ever built

## Biggest Metal Show Opens October 19

Occupying nearly five acres of floor space, exhibits in excess of 400 will outnumber those at any previous Metal Show. Scheduled for October 19 through 23 the 35th Annual National Metal Exposition will be held at the Municipal Auditorium in Cleveland, Ohio. Attendance is expected to exceed 75,000 persons, and predictions are that approximately 40,000 of this total will be engineers and metallurgists. Sponsor of the show is the ASM.

In addition to the exhibition area, space has been obtained in the downtown hotels for the various technical meetings of the National Metal Congress to be held in conjunction with the exposition. Technical papers will be presented at these meetings by all four cosponsoring societies, ASM, AWS, AIMME and the Society for Non-Destructive Testing.

Additional information regarding dates and subjects of meetings and reservations can be obtained from W. H. Eisenman, Managing Director, National Metal Congress and Exposition, 7301 Euclid Ave., Cleveland 3, Ohio.

## Use of Plastics To Attain New Peak

Use of plastics will reach a record high this year according to the Society of the Plastics Industry. Sales figures for the first five months of 1953 show an increase of approximately 40 per cent over those of the comparable period of 1952. Actual sales of thermosetting, thermoplastic, extruded plastics and molds were as follows:

| | 1953 | 1952 | % Increase |
|---|---|---|---|
| Thermosetting Molded Products | $43,885,644 | $32,430,410 | 35 |
| Thermoplastic Molded Products | 57,557,860 | 36,798,223 | 57 |
| Extruded Products | 9,426,874 | 8,159,431 | 15 |
| Molds | 6 216,563 | 4,998,506 | 25 |
| Total | 117,086,941 | 82,340,068 | 43 |

## Ball Jointed Manifold Solves Vibration Problem

An unusual exhaust manifold using ball and socket connections prevents exhaust fume leakage in an armored Army personnel carrier. Powered by a 375 hp Continental engine, the vehicle will travel at a maximum speed of 35 mph, and over logs, rocks and shell holes, up and down steep

slopes. To prevent any possibility of exhaust fume leakage under such conditions endangering infantrymen and crew, something special was required.

The manifold consists of a series of tubes connected by "balls" which relieve stresses due to vibration or thermal expansion and contraction. By careful selection of materials, Ryan Aircraft Co. en-

# Any way you look at it this Thermometer is *Easy Reading*

You've been asking for a dial thermometer like this—A thermometer that can be positioned and firmly locked at any practical angle—now you can have it!

No stretching or straining to see this thermometer. Easy to adjust to required new positions before or after installation. No risk of the multi-angle selector working loose. A specially designed selector assures positive locking at every practical mounting angle and a few turns of *one* nut lock the selector securely.

These instruments, supplementing USG's complete line of Gotham temperature indicators, are designed to fit all standard connections and are available in all standard ranges. If you have a number of applications requiring "odd angle" mounting these new multi-angle thermometers will reduce the number and variety of instruments you have to carry in stock.

Before you order an angle thermometer be sure you see USG's new Gotham Multi-Angle Thermometer.

UNITED STATES GAUGE

## ADVANTAGES

1. Positive locking in every conceivable angle.
2. Reduces the number and variety of instruments required in your maintenance stock.
3. Provides that extra "odd angle" instrument which normal stock does not furnish.
4. Easy to change to any desired angle, before or after installation.
5. Saves engineers time when writing specifications.
6. Affords easy reading at odd angles.

United States Gauge
Division of American Machine and Metals, Inc.
Sellersville 2, Pa.

Gentlemen:

We'd like to know more about the new USG Multi-angle Thermometer. Please get in touch with us.

Name_____ Title_____

Company_____

Address_____

City_____ Zone_____ State_____

JUNIOR "BRAIN": This new electronic calculator fills the gap between the "giant brains" and smaller calculators. Called the IBM Magnetic Drum calculator, the new machine combines this advanced memory device and the stored program concept of IBM's recently announced "701" (*Machine Design*, May, 1953, Page 236) with new high-speed reading capacity in conventional punched-card equipment for commercial and engineering use

gineers, designed the manifold so that manifold heating expands the balls in the sockets to tighten the seal. Materials used also had to resist corrosion and oxidation in

the presence of hot exhaust gases. A corrosion-resistant nickel-alloy cast iron, Ni-Resist, is used for the balls. Chromium-nickel stainless steel tubing forms the main part of the manifold.

---

**A new research center,** said to be the most modern in the entire electrical industry, is under construction for Westinghouse Electric Corp. Built on a 70-acre plot near Pittsburgh, the research center is scheduled for completion early in 1955. Approximately one - third larger than the present laboratories and providing room for future expansion, the new center replaces the present laboratories located nearby since 1916. Design of the new center is such that the working area can be enlarged by rearranging interior walls and facilities.

Also under construction for Westinghouse is a $6 million steam and gas turbine research and development laboratory at South Philadelphia. To be completed this fall and ready for use in the summer of 1954, the four story building includes 750 tons of structural steel.

## Electron Beam Interferometer

Research on the wave properties of electrons has resulted in the development of an interferometer that utilizes electron beams to produce interference fringes for length measurements in much the same way as conventional optical interferometers use light beams. National Bureau of Standards scientists employ diffraction from an extremely thin crystal as a means for splitting and recombining an electron beam and use an electron optical system for viewing the resulting interference phenomena.

The NBS electron interferometer greatly extends the range of light interferometers used in the direct measurement of length. In addition, the instrument constitutes an extremely sensitive device for measuring gradients of magnetic and electrostatic fields—analogous to refractive indices in optical interferometry — and provides a means for obtaining additional information on the wave nature of the electron. Other suggested applications of the method include studies of the energy levels in solids and an absolute determination of Planck's constant.

**Powdered iron** will be produced at the rate of 50,000 pounds per day at a new plant, soon to be started in Toledo, Ohio, by the Republic Steel Corp. In entering this field, Republic becomes the first major steel company to do so on a commercial scale.

---

**A new magnet material** composed essentially of barium and iron oxides will be manufactured by the Carboloy Dept. of General Electric Co., under license from

ANNOUNCING

# First Conference On Mechanisms

*cosponsored by Purdue University and Machine Design Magazine*

**OCTOBER 12-13, 1953** **PURDUE UNIVERSITY**
**Lafayette, Indiana**

To promote better understanding, design and application of mechanisms in automatic machinery, the Editors of MACHINE DESIGN and the Mechanical Engineering Dept. of Purdue University have collaborated in bringing together for this program a group of top authorities on the most recent developments in this important field of design.

All machine designers and other engineering personnel interested in the design and development of mechanisms are cordially invited. Registration fee is $20. To register in advance, send in postcard opposite Page 176. For details of overnight room accommodations, see Page 188.

## PROGRAM

**Session 1—Mechanisms Today**

**Mechanisms and Their Classification**
A. S. HALL, *Professor, Mechanical Engineering, Purdue*

**Session 2—Mechanism Problems with High-Speeds**

**Recognition and Treatment of Acceleration**
A. HOLOWENKO, *Assoc. Professor, Mechanical Engineering, Purdue*

**Design and Application of Noncircular Gears**
H. E. PEYREBRUNE, *Vice Pres., Eng., Miehle Printing Press & Mfg. Co.*

**Utilizing Irregular Gears for Inertia Control**
W. W. SLOANE, *Vice Pres., Eng., Goodman Mfg. Co.*

**Session 3—Procedures in Mechanism Design**

**A Simplified Approach to Linkage Design**
E. W. PIKE, T. R. SILVERBERG, P. T. NICKSON,
*Equipment Engineering Div., Raytheon Mfg. Co.*

**Designing Cams with the Aid of Computers**
R. F. GRIFFIN, *Research Engineer, Warner & Swasey Co.*

**Session 4—Applications of Mechanisms in Automatic Machinery**

**A Systematic Method of Correlating Motions**
J. LONGSTREET, *Chief Textile Engineer, Warner & Swasey Co.*

**Round Table Discussions with Authors**

**Conference Committee:**

W. R. SPILLER, *Vice President of Eng., Harris Seybold Co.*
W. A. WITHAM, *Executive Eng., Miehle Printing Press & Mfg. Co.*
M. S. CURTIS, *Vice President of Eng., Warner & Swasey Co.*
W. A. PATZER, *President and Chief Engineer, ABT Mfg. Co.*
E. S. AULT, *Professor of Machine Design, Purdue University*
A. S. HALL, *Professor of Mechanical Eng., Purdue University*
B. L. HUMMEL, *Associate Editor, Machine Design*
R. W. BOLZ, *Associate Editor, Machine Design*

Philips Laboratories Inc. Properties of the new material approach those of alnico and no strategic materials are used in its composition.

### Synthetic Resin Seals Porous Castings

Aluminum and magnesium castings may be sealed oiltight by a new vacuum-pressure impregnation process. Sealed castings may be machined without affecting the seal and will withstand both gas and liquid pressure at 150 degrees centigrade. Resin used withstands attack by chemicals, oil and gasoline after curing, and is soluble only in hot, strong caustic or alkaline solutions.

Now being used at Pratt and Whitney Aircraft Plants to impregnate jet and piston engine castings up to 80 inches in diameter, the process consists of three main operations. Castings are first placed in 1500-gallon autoclaves under a 28 inch vacuum to eliminate air pockets. General Electric Co. 3255 Permafil is then introduced and light pressure applied for 20 minutes. A four hour baking, or cure, completes the process.

---

**Set Screw & Mfg. Co.** has acquired the facilities for manufacturing and selling the line of offset self-locking set screws, formerly marketed by Shakeproof. Now known as the "Setko offset self-locking set screw," this screw is particularly suited for applications requiring slotted screws. Especial-

## Machinery Exports Reach New High

How important is the export market to machinery manufacturers in the capital goods field? Which areas of the world represent the largest markets and what have been the trends since before World War II? The accompanying tables, adapted from a recent bulletin issued by the Council for Technological Advancement of the Machinery and Allied Products Institute provide a basis for answering these and similar questions.

Machinery and equipment exports in 1952 totalled practically $3 billion. How this was distributed among the various types of machinery is shown in TABLE 1. The $3 billion figure represents 20 per cent of total U. S. exports, or almost 25 per cent of nonmilitary exports. TABLE 2 indicates the importance of export markets in relation to total production of capital goods machinery.

Relative importance of the various parts of the world in terms of the export market is illustrated in TABLE 3, showing that the Western Hemisphere absorbs 60 per cent of all machinery exports. On the other hand, two-thirds of the metalworking machinery exports go to Europe.

How the export picture has changed since pre-World War II days is apparent from TABLE 4. The index is adjusted to allow for inflation, and therefore is a fair indication of physical volume. Again, the Western Hemisphere shows the biggest jump in export business.

According to the report, exports are currently declining from the record levels of 1952 but are still at a high level by all previous standards. Inasmuch as the report covers only capital goods equipment, large and important areas of the machinery manufacturing field serving consumers, such as automobiles and domestic appliances, naturally do not show up in the tables.

**Table 1—U. S. Machinery Exports**

(1952)

| | | |
|---|---|---|
| Electrical machinery and apparatus | $687.3 million | |
| Industrial machinery | 1,550.0 | |
| Construction, mining and pumping | | 500.0 |
| Metalworking | | 261.5 |
| Textile, sewing and shoe | | 107.4 |
| Engines and turbines | | 155.2 |
| Office machines and parts | 89.1 | |
| Printing trades machinery | 28.3 | |
| Agricultural machinery and implements | 140.8 | |
| Tractors, parts and accessories | 322.5 | |
| Railroad and transit equipment | 79.7 | |
| Scientific and professional equipment | 55.8 | |
| Total | $2,953.5 million | |

**Table 2—Percentage of Exports To Total Factory Shipments,**

(1951)

| | |
|---|---|
| Engines, Turbines and parts | 14.3 |
| Construction, mining and pumping machinery | 15.8 |
| Metalworking machinery | 19.3 |
| Textile and sewing machinery | 22.0 |
| Printing trades machinery | 17.4 |
| Agricultural machinery and implements. | 11.2 |
| Tractors, parts and accessories | 22.8 |
| Electrical machinery and apparatus | 5.5 |
| Railroad and transit equipment | 4.2 |
| Office machines and parts | 16.2 |
| Scientific and professional instruments | 4.1 |

**Table 3—Percentage Exports into Selected Areas**

(1952)

| | Northern N. America | Latin America | Europe | Asia | Other Areas |
|---|---|---|---|---|---|
| Agricultural machinery, excluding tractors | 53.6 | 25.5 | 6.9 | 3.2 | 10.8 |
| Tractors, parts and accessories | 36.6 | 26.8 | 11.7 | 10.4 | 14.5 |
| All other machinery except electrical | 24.2 | 30.8 | 23.5 | 11.5 | 10.0 |
| Engines and turbines | 24.3 | 35.3 | 12.7 | 15.9 | 11.8 |
| Construction and mining | 23.3 | 29.6 | 14.2 | 11.1 | 11.8 |
| Metalworking | 16.1 | 9.8 | 66.6 | 5.7 | 1.8 |
| Electrical machinery and apparatus | 27.5 | 38.0 | 14.8 | 13.1 | 6.6 |
| All machinery and equipment | 28.0 | 31.7 | 19.3 | 10.9 | 10.1 |

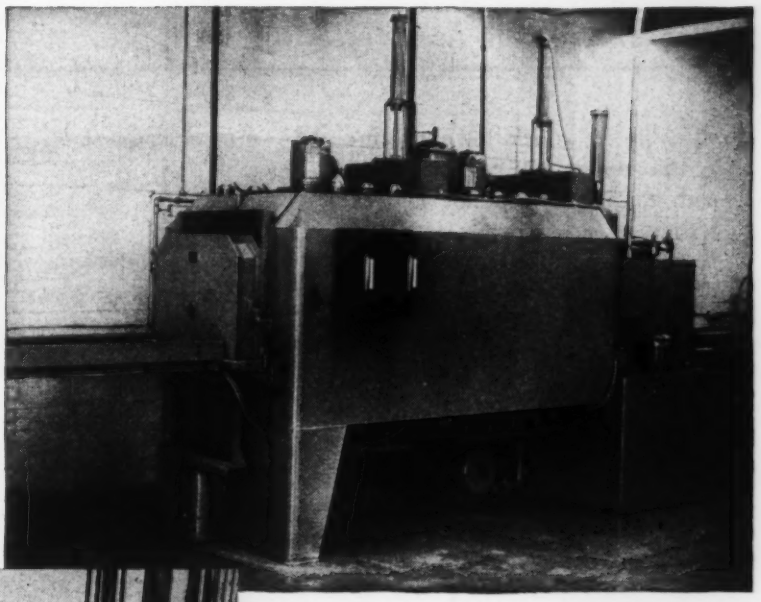
**Table 4—Index of 1952 U. S. Machinery Exports**

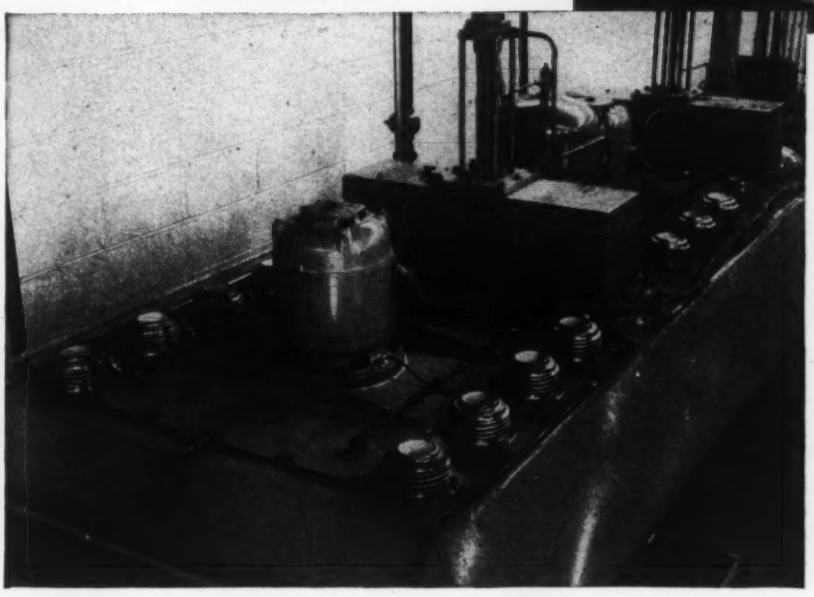
(1938=100)

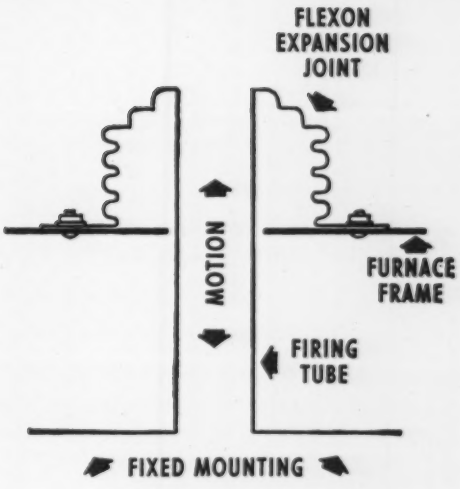
| | Northern N. America | Latin America | Europe | Asia | Total All Areas |
|---|---|---|---|---|---|
| Agricultural machinery, excluding tractors | 712 | 181 | 359 | 510 | 343 |
| Tractors, parts and accessories | 424 | 441 | 194 | 623 | 328 |
| All other machinery except electrical | 675 | 531 | 218 | 180 | 329 |
| Engines and turbines | 650 | 492 | 363 | 431 | 496 |
| Construction and mining | 729 | 309 | 382 | 157 | 323 |
| Metalworking | 591 | 592 | 156 | 44 | 148 |
| Electrical machinery and apparatus | 596 | 405 | 208 | 364 | 339 |
| All machinery and equipment | 608 | 446 | 216 | 225 | 332 |

*Here's how*

# FLEXON EXPANSION JOINTS solve a difficult motion problem in this heat treating furnace

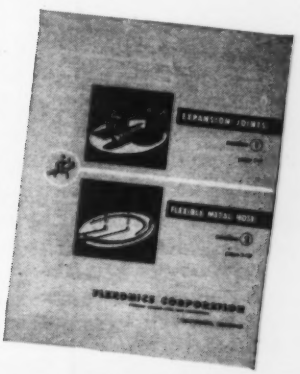







In the heat treating furnace illustrated above, which is manufactured by Ipsen Industries, Rockford, Ill., the unit is brought to temperature by burning gas in vertical tubes that extend through the furnace. Thermal expansion of these tubes at 1000° F. presented a mounting problem that was solved by attaching the free end of the tube to a FLEXON Expansion Joint, which in turn is mounted on the furnace frame as shown in the drawing. To combat the high temperatures and corrosive conditions, the expansion joints are fabricated from No. 321 stainless steel.

This is the type of problem that is a specialty of Flexonics Corporation. Whenever you have a connection problem, whether it be caused by expansion, flexation or vibration, let Flexonics know-how solve it for you.



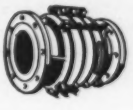
Flexonics Catalog No. 128 gives full information on Flexon Expansion Joints and other motion control problems. See also the Flexonics catalog in Sweet's.

**Flexonics** *Corporation* **EXPANSION JOINT DIVISION**
**1339 S. THIRD AVENUE · MAYWOOD, ILLINOIS**

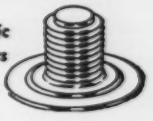
**FORMERLY CHICAGO METAL HOSE CORPORATION**
In Canada: Flexonics Corporation of Canada, Ltd., Brampton, Ontario

Flexon identifies products of Flexonics Corporation that have served industry for over 50 years.

*Flexible metal hose*


*Expansion joints*

*Aircraft components*

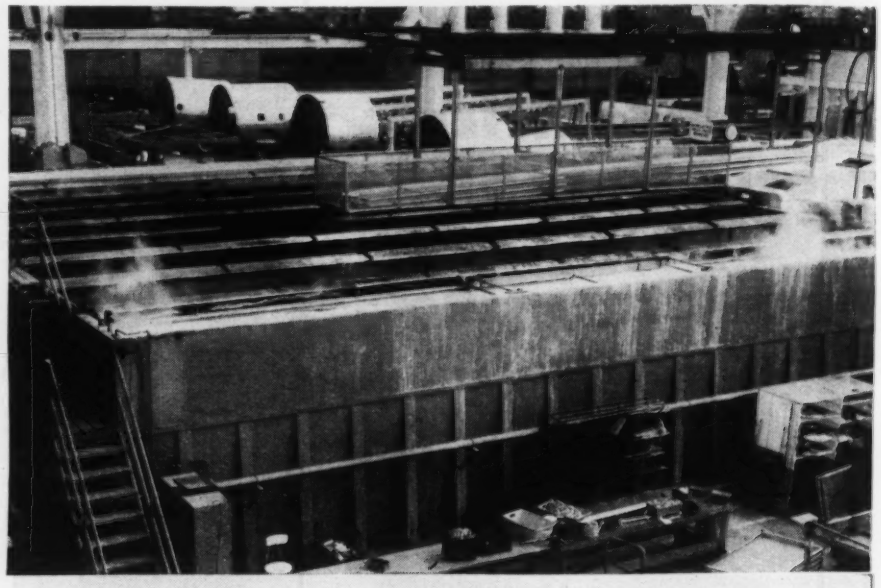

*Metallic bellows*

ly valuable in knock-down assemblies, the screws will remain in the tapped holes and are not lost in shipping.

## Robot Devices Monitor Tests at Aero Lab

A special 35-foot graphic supervisory control panel, interlinked with five other control panels, will function as the nerve center of an automatic test monitoring system at the U. S. Navy's new $30 million aeronautical turbine laboratory being built at West Trenton. N. J. The control panels, developed by Minneapolis-Honeywell Regulator Co.'s industrial division, will provide remote operation of two altitude chambers and three test cells.

When completed, the test cells will handle the bulk of test and experimental work on Navy jet and turboprop engines. Altitudes to 65,000 feet and speed-of-sound air velocities can be created in the test cells to simulate actual flight conditions.



BIG BATHTUBS: Nine tanks, 52 feet long, 12 feet deep and 4 feet wide are used in the new chromodize-iridite method of preparing and cleaning aluminum prior to painting at Lockheed Aircraft Corp. The new process deposits an iridescent chemical film by simple chemical immersion and is said to be much more efficient and economical than anodizing. In addition to cutting processing time in half, the process is said to provide a better base for paint adhesion and permit handling of parts using dissimilar metals, whereas anodizing can be used only with aluminum in the processing tank

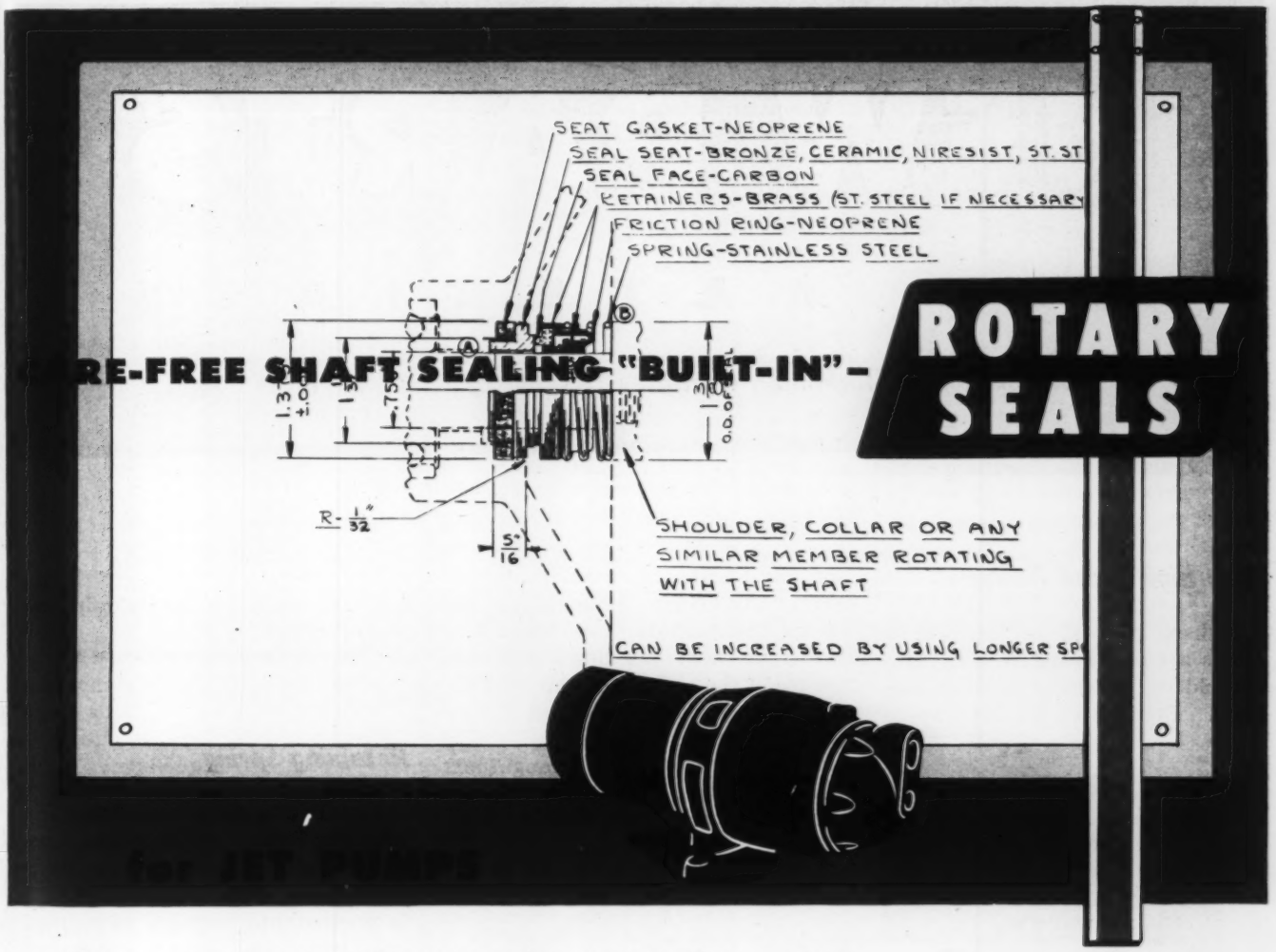
## New Devices at NBS Test Effects of High Acceleration

Recently completed shock and acceleration simulation devices, including a 91-foot drop tower, air-guns, wind tunnel and centrifuges, are providing improved facilities for the ordnance development activities of the National Bureau of Standards. The new equipment is used primarily to study effects of high accelerations — similar to those to which ordnance projectiles are subjected in normal use—on experimental ordnance components. Major equipment housed in the Bureau's Air Gun Building includes two air guns, one of them 96 feet long; a wind tunnel, used in related work, with a velocity of 300 feet per second; and four centrifuges, one of which can produce accelerations of 60,000$g$ on one-pound specimens. The drop tower, located near the Air Gun Building, is used for studying effects of shock impacts on experimental objects. Test objects are elevated to heights up to 87 feet, 8 inches and dropped onto various anvils—steel, concrete, wood or sand.

CAST COLUMN: One of four such columns, this 200-ton steel casting is part of an 8000 ton capacity forging press being built for the USAF. One of the largest castings ever produced by United Engineering and Foundry Co., the column is 52 feet long, 7 feet wide and 9 feet high

---

**A new company,** the Bristol Bearing Co., has been formed to take over the entire operation of the Preferred Bearing Co. of Bristol. Acquired by Walter P. Jacob, Chairman of the Board of the Hartford Electric Steel Co. and business associates, the new company will produce a line of unground, pressed, radial and thrust ball bearings.


SEAT GASKET-NEOPRENE
SEAL SEAT-BRONZE, CERAMIC, NIRESIST, ST. ST
SEAL FACE-CARBON
RETAINERS-BRASS (ST. STEEL IF NECESSARY
FRICTION RING-NEOPRENE
SPRING-STAINLESS STEEL
SHOULDER, COLLAR OR ANY SIMILAR MEMBER ROTATING WITH THE SHAFT
CAN BE INCREASED BY USING LONGER SP
RE-FREE SHAFT SEALING "BUILT-IN"–
ROTARY SEALS

When pumps are built for day-in, day-out operation on farms and in other remote locations, far from service men, they must be just about trouble-proof in every detail. That's why leading makers of such equipment have long since standardized on Rotary Seals to assure *Shaft Sealing with Certainty* at the heart of their units. The practical Rotary Seal principle, experience-based Rotary Seal engineering, Rotary Seal's precision manufacturing add up to positive protection for the life of the pump.

Whether you make pumps or some other equipment where difficult use conditions demand *certainty* in Shaft Sealing, you'll find that Rotary Seals will do the job best. Call in Rotary Seal engineers at the drawing board stage of your new units, if you can; their long experience in many fields can often suggest the simplest design approach from a Shaft Sealing standpoint. Write us today!

**THE ROTARY SEAL PRINCIPLE**

*is the original approach to a practical solution of a universally troublesome problem. Our booklet "SEALING WITH CERTAINTY" explains and illustrates the principle. We're glad to send it to you without obligation.*

THE mechanical seals for ROTARY SEAL COMPANY rotating shafts

2032 NORTH LARRABEE STREET
CHICAGO 14, ILLINOIS, U.S.A.

# NEW PARTS AND MATERIALS

For additional information on these new developments, see Page 209

## Ultra High Speed Relays

Millisec plug-in, factory sealed relays are now available with either gold or platinum-rhodium contacts. Because of its high speed

and low current, low voltage contact operations, gold is used on the relays in the range of 0 to ¼ amp at 0-110 v dc. Platinum-rhodium is employed in the range of 0 to ½ amp at 10-110 v dc. Made by **Stevens-Arnold Inc.**, 22 Elkins St., South Boston, Mass.

For more data circle MD-37, page 209

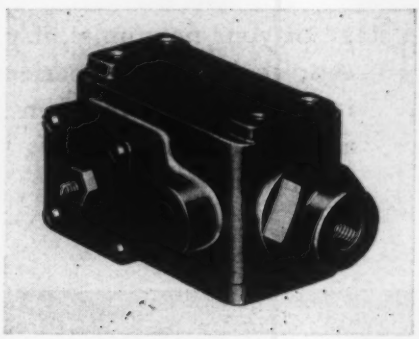
## Vinyl Resin

Marvinol VR-22 is designed for dry blend feed of extruded products such as wire jacketing, tubing, welting and hose. It is a straight polyvinyl chloride resin of high molecular weight, and it fuses quickly, producing smooth, uniform extrusions which are free from "fish eyes." The resin can be formulated with high amounts of plasticizer of varying types. Tests show that compounds made from the material have excellent inherent heat stability and, because of the high molecular weight, excellent resistance to heat deformation and compression under load. Developed by Naugatuck Chemical Div., **United States Rubber Co.**, Rockefeller Center, New York 20, N. Y.

For more data circle MD-38, page 209

## Small Pressure Regulator

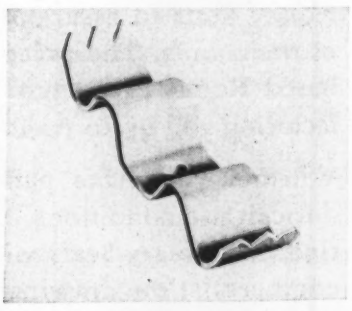
For use in air or oxygen systems, Model 10700 pressure-reducing regulator weighs 8 oz and measures 1⅝ by 1 15/16 in. It takes inlet pressures up to 2000 psi, has adjustable output pressure from 50 to 300 psi, and handles flows up to 300 liters per minute. Output pressure variation from zero to full flow is approximately 15 per cent. Greater flow can be handled if pressure is allowed to drop more than 15 per cent from zero to full flow. Regulator is made by **Aro Equipment Corp.**, Bryan, O.



For more data circle MD-39, page 209

## Retaining Spring

Installation is accomplished by pressing the spring into position between two plastic studs with the fingers. As the spring is pressed into position, its toothed end legs bend inward; once in position, it locks. This spring is designed for ⅞-in. stud spacing; other sizes can be produced. Available from Shakeproof Div., **Illinois Tool Works**, 2501 North Keeler Ave., Chicago 39, Ill.



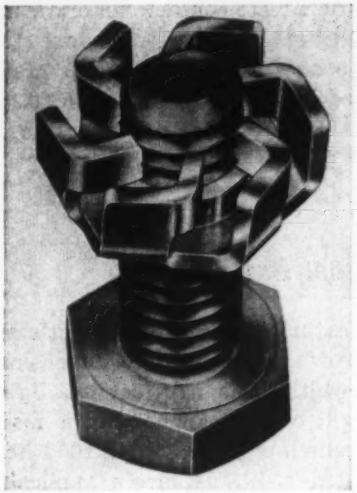
For more data circle MD-40, page 209

## Locknut

Spin-down locknut applies a permanent, vibration-proof grip only after it actually contacts the work. At point of contact with the work, a

quarter turn takes up all play. As the nut is drawn tight, six threaded tines bite into the bolt in a shrinking action caused by the concave base which flattens as the nut is drawn tight. The nut is unaffected by water, oil or heat up to 550 F and is available in No. 8-10 and ¼-in. sizes in both National Fine and National Coarse threads from **Thompson-Bremer and Co.**, 520 North Dearborn St., Chicago 10, Ill.

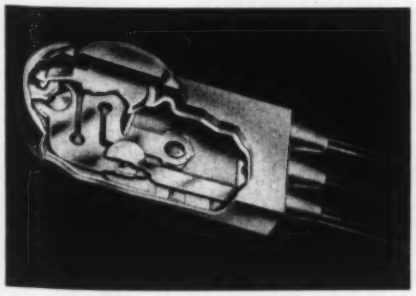
For more data circle MD-41, page 209



## Waterproof Switch

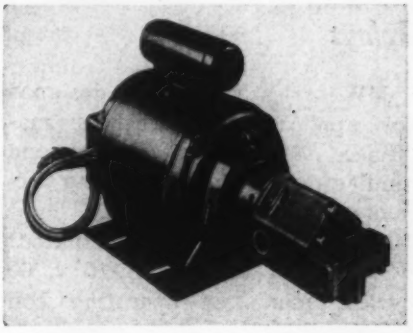
Snap-action, single-pole, double-throw, three-wire type switch features sine curve design and miniature size. Switch is made in accordance with U. S. Army specification 60-977-2, Class B, covering waterproofing and corrosion resistance. Mechanism will operate without damage in temperatures ranging from −65 to 165 F. Electrical capacity is 20 amp resistive at 28 v dc, 10 amp resistive at 110 v ac. Can be used where water, oil, grease, dust, grit, dirt or other harmful factors are present, such as on packaging and bottling machines, vending machines, dredges, farm machinery, refrigeration machinery, marine equipment, and industrial machines. Made by **Control Products Inc.**, Sussex St., Harrison, N. J.

For more data circle MD-42, page 209



## Hydraulic Pumps

LA and LB Series pumps are now available with integral electric motor drives for low-capacity, low-pressure applications. They can be used with oils as well as with other liquids having a substantial oil base. Capacities range from 0.25 to 4.5 gpm at 100 psi. Maximum working pressures may be increased to 200 psi with power requirements not to exceed ½ hp. Optional internal relief valves make possible the variation of relief pressures between 50 and 200 psi.



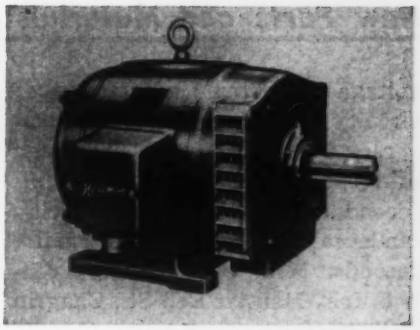
Made by Oil Hydraulics Div., **Webster Electric Co.**, 1900 Clark St., Racine, Wis.

For more data circle MD-43, page 209

## Integral-hp Motors

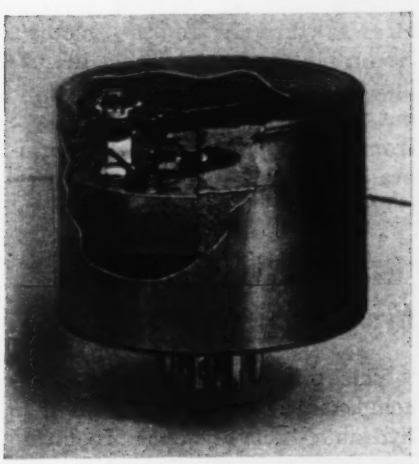
Squirrel cage and open dripproof types feature primary windings of high conductivity, heat-resistant synthetic enameled wire, dynamic balancing of rotor and fan, and side-mounted conduit boxes. The totally enclosed fan-cooled squirrel cage motor features stator and rotor cores of insulated, high-permeability steel laminations, secondary windings of cast aluminum alloy or copper or brass bar, standard size bearings. Dripproof wound rotor and squirrel cage types feature stator and rotor cores of insulated high-permeability steel laminations, standard size bearings, and uniform temperature distribution. British made, the motors are available in sizes to 230 hp from **Newman Industries (America) Inc.**, 43 Broad St., New York 4, N. Y.

For more data circle MD-44, page 209



## Meter-Relay

Model 265 nonindicating plug-in meter-relay has a balanced movement, self locking contacts and sensitivity as great as 0.2 ma. Sealed in a round metal can, the relay can be furnished with either an octal plug connector or other type of sealed header. The jeweled movement is shock mounted to withstand jars and vibration.



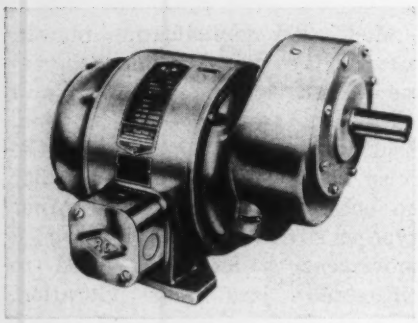
Sensitivity ranges from 0.2 ma to 50 amp, or 0.05 mv to 500 v. Copper oxide or crystal diode rectifiers are used for ac operation. Contacts lock in by a holding coil in the relay. Accuracy is factory adjusted to within 3 per cent of the specified

voltage or current; adjustment of circuit resistance can bring accuracy to within 1 per cent. Range of response time is from 1 millisecond to 10 seconds. Time delay can be calibrated in seconds or milliseconds. Made by **Assembly Products Inc.**, Main at Bell St., Chagrin Falls 97, O.

For more data circle MD-45, page 209

## Speed Reducer

Converts motor speed into low-speed, high-torque output in one step. Rotation of endbell allows connection of output shaft to the load either above, below, right or left of the drive motor. Unit features oil bath lubrication of all gears, quiet running helical gears and transmission of lateral load

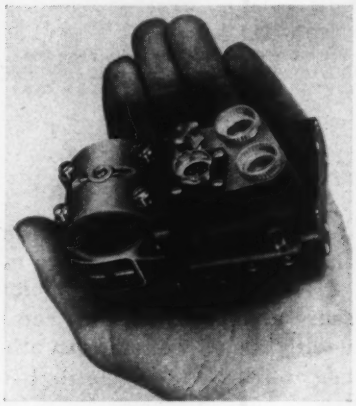


stresses directly to the motor's mounting base. Available in ratings from ½ to 5 hp and in output speeds from 190 to 520 rpm from **Reuland Electric Co.**, Alhambra, Calif.

For more data circle MD-46, page 209

## Hydraulic Servovalve

This miniature single-stage uncompensated servovalve is used in hydraulic servosystems requiring fast response and small size. Of balanced symmetrical twin-piston design, it operates smoothly under adverse vibration and lateral acceleration conditions. The valve has no external leakage—a small drain line returns leakage oil to the pump. The body and pistons are hardened, precision-lapped alloy steel: working pressure is 200 to 3000 psi; power to load, approximately 5 hp (max); steady state

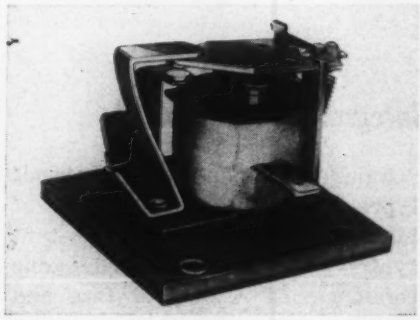


leakage, 0.1 to 0.2 gpm. Made by **Midwestern Geophysical Laboratory**, 3401 South Harvard, Tulsa, Okla.

For more data circle MD-47, page 209

## Relays

MW series relays are designed for application in washing machines, dishwashers, dryers and similar appliances requiring relays for timing circuits. Type MW1A-115-60 is voltage actuated; nominal coil voltage is 115 v, 60 cycles; maximum operating coil voltage, 140; pull in, 90 v or less; contacts, 3/16-in. fine silver rated at 5 amp, 115 v ac noninductive load; contact arrangement, single-

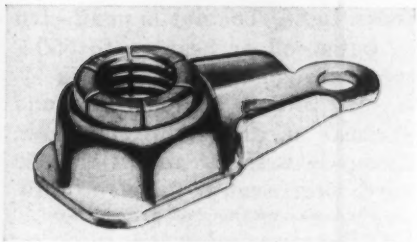


pole, single-throw, normally open; contact pressure, 30 grams; insulation test, 500 v rms. Current actuated type MW1A-4 AMP requires nominal coil current of 5 amp, maximum coil current of 6 amp; pull in is 4 amp or less. Insulation test, contact material, arrangement and pressure are the same as for MW1A-115-60. Produced by **Potter & Brumfield**, 1200 East Broadway, Princeton, Ind.

For more data circle MD-48, page 209

## Anchor Nut

Featuring increased strength and narrow AN envelope dimensions on width, this self-locking, lightweight one lug anchor nut is made of cadmium plated SAE 1050 heat treated steel. It meets applicable requirements of specifications AN-N-5, AN-N-10. Available in both



¼-28 and 5/16-24 thread sizes from **Nutt-Shel Co. Inc.**, 811 Airway, Glendale 1, Calif.

For more data circle MD-49, page 209

## Plastic Pipe, Tubing

Pipe, tubing and fittings are made of Alpha Forty, a special compound of vinyl chloride polymer of high molecular weight. The material retains the unmodified properties of straight p.v.c., and is an extremely hard, tough and rigid product with outstanding chemical resistance. Pipe is resistant to most inorganic chemicals and organic materials and at ordinary temperatures is unaffected by alkalies, acids, salts, oxidizing agents, oils, greases, alcohols, gasolines and carbon tetrachloride. Ultimate tensile strength is of the order of 7000 psi.; compressive strength is 12,000 psi.; flexural strength is 13,000 psi. Impact strength is 0.75 lb-ft per in. of notch; deformation under load is 0.8 per cent in 24 hours. Water

# here's why Klincher LOCKNUTS

are being

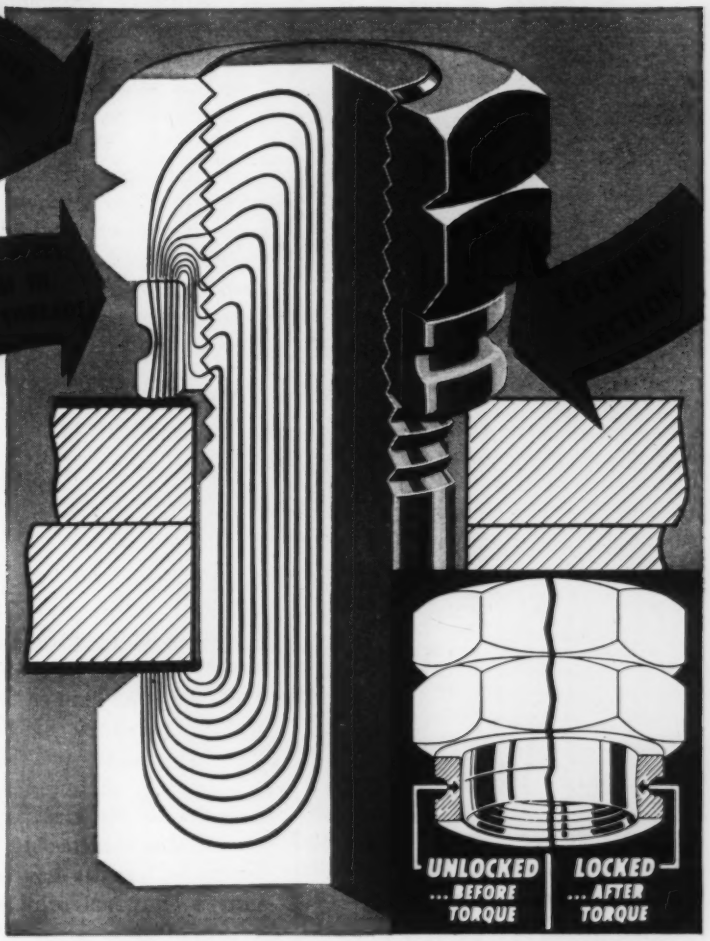
## SPECIFIED

**for High temperature fastening up to...**

## 1600° (F)

***...particularly where high frequency vibration, tensile strength and re-usability are factors!***

Klincher Locknuts are specially designed to give reliable performance in critical applications at temperatures up to 1600° F. The Klincher principle of load distribution reduces the high stress concentration and torsional load usually found in the first two or three threads. Even under severest vibration, nut remains positively locked and there's no danger of galling, seizure or stud wear . . . *and* nut remains fully re-usable.



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- Ideal for hand and power wrenches.
- Manufactured in stainless and other materials, in machine screw sizes No. 4 and up, and all fractional sizes.
- Easy to inspect for positive assurance of tight connection.
- Free running feature reduces assembly time.
- Only one piece to stock and handle.

Klincher's unique construction makes it possible in some cases to use a smaller hex size . . . an aid to fitting in tight places where minimum clearances are present. Write for data and experimental samples, giving size and application. Address Dept. **MD-9.**

**Klincher**
**LOCKNUT CORPORATION**
2153 HILLSIDE AVE
INDIANAPOLIS, INDIANA

absorption is 0.2 per cent in 24 hours at 25 C. Pipe is stocked in 10 and 20-ft lengths in both standard and extra heavy weights, from ½ to 4-in. nominal pipe size. Threaded or sleeve-type fittings are

available in sizes from ½ to 2-in.; larger sizes are fabricated to order. Styles include standard tees, 45 and 90-degree elbows, nipples, plugs, couplings, and blind or companion flanges. Made by **Alpha Plastics Inc.**, 14 Northfield Road, West Orange, N. J.

For more data circle MD-50, page 209

## High-Speed Commutator

Designed for use in radio and wire telemetering, multichannel switching and automatic rapid rate

sampling, this high-speed switching commutator is readily adaptable to provide a variety of circuit patterns and a number of channels. Dustproof construction and noise-free operation are claimed throughout an operating life of at least 100 hours at 5 rps. With precious metal contacts and brushes and an external adjustment for phase relationship between poles, the commutator gives clean electrical make and break. It is available with one or two poles with a maximum of 45 terminals on one pole and 15 terminals on the second pole. Two contacts can be had per terminal. The unit will meet performance specifications under 50 *g* steady state acceleration and will operate under 10 *g* vibration up to 1000 cycles per second. Total weight is 3½ oz. Made by **G. M. Giannini & Co. Inc.**, 117 East Colorado St., Pasadena 1, Calif.

For more data circle MD-51, page 209

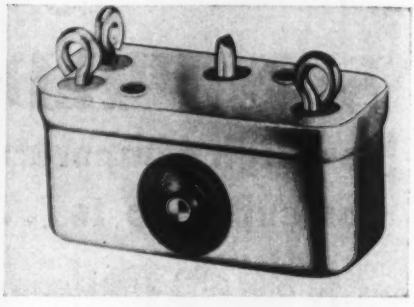
## Wire Braided Hose

Ironsides butane-propane hose combines layers of horizontally braided steel wire and rayon cord reinforcement and a nonporous and oil-resistant rubber tube. Minimum burst pressure is 1750 psi, with actual burst pressure exceeding 2300 psi. Each length has two separate static wires, interlaced with the reinforcing braids, to insure full static conductivity. Made on a mandrel which insures uniform inside diameters for quick, positive coupling, the hose is available in sizes from ½ to 2 in. from Quaker Rubber Corp., Div. of **H. K. Porter Co. Inc.**, 1932 Oliver Bldg., Pittsburgh 22, Pa.

For more data circle MD-52, page 209

## Snap Switches

Hermetic sealing with inert gas under pressure makes possible exposure to changes in pressure and temperature, high rates of acceleration, shock and vibration, and exposure to moisture, dust, fungus and a number of other corrosive elements. The hermetic enclosure will withstand 100 psi internal pressure. The switch has a rapid contact traverse rate with negligible contact bounce. It may be cycled to 750 operations per minute. Force required to operate the switch is small. Rated for at least 100,000 operating cycles at 10 amp, 115 v, 60 to 400 cycles ac noninductive

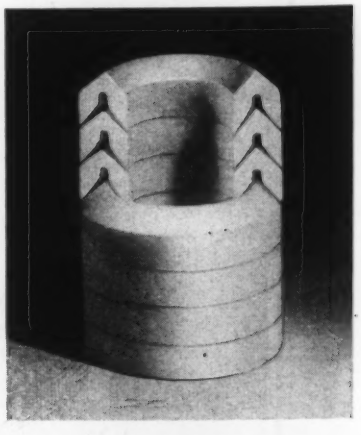


load, switch life exceeding 50,000 operations may be expected at 15 amp. Temperature rise will not exceed 65 C under occasional or standby operation at 20 amp. Available in several forms for various applications, the switch measures 1 11/32 by 41/64 by 13/16-in. overall with 0.312 by 0.520-in. mounting centers and weighs 0.60 oz. Made by **Haydon Switch Co.**, 232 North Elm St., Waterbury 20, Conn.

For more data circle MD-53, page 209

## Gland Packings

Completely inert to hydraulic fluids, oils, petroleum products, acids, bases and solvents, series S-

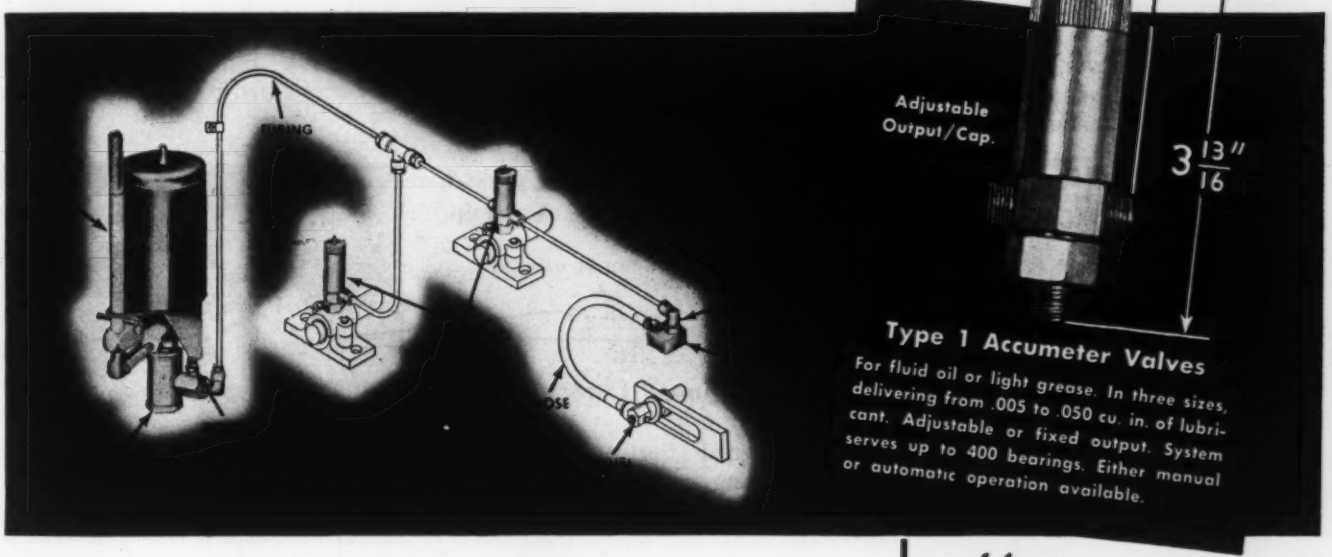


2500 Vee-Seal flexible Teflon packings are suitable for service in valve stems and hydraulic cylin-

*Designed*...to eliminate hit-or-miss machine lubrication

# ALEMITE Accumeter® CENTRALIZED LUBRICATION

## extends the protection of automatic lubrication to virtually any machine




**Type 1 Accumeter Valves**

For fluid oil or light grease. In three sizes, delivering from .005 to .050 cu. in. of lubricant. Adjustable or fixed output. System serves up to 400 bearings. Either manual or automatic operation available.

Centralized lubrication with Alemite Type I Accumeter can make your machines produce more, last longer, and cost less to run—*impressive savings at low cost!* This simple, single-line system is completely versatile—easy to design, easy to build into any machine because valves fit directly on bearings, replacing grease fittings, oil cups or reservoirs.

**In seconds,** in a fraction of the time required for hand lubrication, Alemite Accumeter Lubrication System delivers the exact, measured amount of clean oil or grease *from one central point* to all bearings of a machine. The machine keeps operating—no production time lost—no bearings are missed. No wonder 95% of big plants buying machine tools specify *centralized lubrication!*

**Type 1 Accumeter Systems** serve single machines or groups of machines with semi-automatic or fully automatic lubrication. It is just one of three types of Accumeter Systems made by Alemite to meet your exacting requirements.

*offers...*

**ALL THESE ADVANTAGES!**

- **Eliminates shutdown time for lubrication. Adds productive time to machine output.**
- **Seals completely against dirt, grit, water all the way from "Barrel-to-Bearing."**
- **Prevents bearing troubles due to neglect or use of wrong lubricant.**
- **Services *all* bearings—including those inaccessible or dangerous—in one operation.**
- **Avoids work spoilage and bearing repairs due to over-lubrication.**

**FACTORY-TESTED . . . FIELD-PROVED**

Proved in the field. Exhaustive tests showed *no variation* in the amount of lubricant discharged . . . even after 73,312 lubrication cycles, *equal to 122 years of twice-a-day service.*

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Please send me my free copy of the Alemite Accumeter Catalogue and Engineering Data Book.

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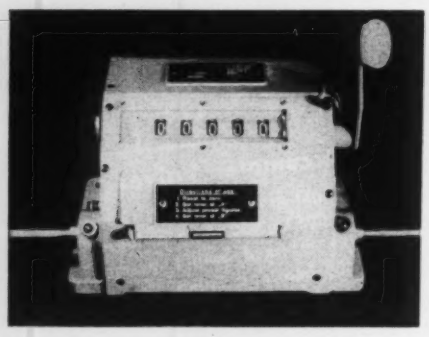
ders, jacks, lifts and pumps. Due to V-type construction, packings are self-sealing and self-adjusting at finger tip gland pressures. Upon application of hydraulic pressure, seal expands against stuffing box and against stem. Useful temperature range of the seals is from −110 to 500 F. Units are available in sets to meet specific requirements and stack heights. Made by **W. S. Shamban & Co.**, 11617 W. Jefferson Blvd., Culver City, Calif.

For more data circle MD-54, page 209

## Predetermining Counters

Featuring a lever reset, these counters are set instantly by grip wheels located under a hinged

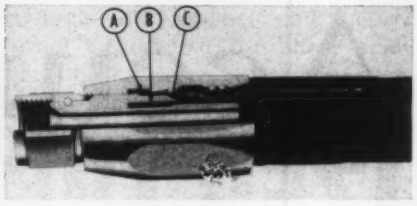


cover. They are available for stroke, revolution and electrical counting, operating to 6000 counts per minute in revolution types, adding in both directions or adding and subtracting. Release is effected in one or two stages by mechanical lever or dipole switch. Made by the Irion & Vosseler Co., of Germany, the counters are available from **Presin Co.**, 5225 Wilshire Blvd., Los Angeles 36, Calif.

For more data circle MD-55, page 209

## Steam Hose

This burst-proof hose is constructed of a natural rubber inner tube reinforced with either one or two plies of high tensile steel wire braid, depending on the hose size. Asbestos braid covers the wire braid, and the outer cover is oil-resistant butyl rubber. The hose features a Little Gem fitting in which the reinforcing braid of the

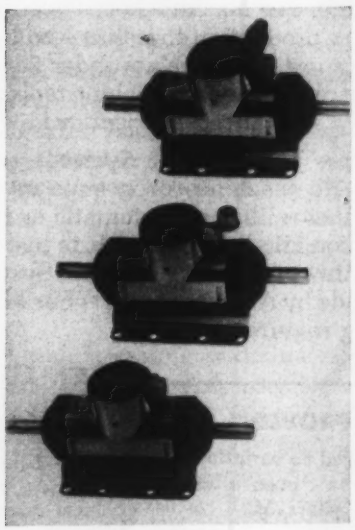



hose alone is clamped between the socket and nipple, while a fluid-tight seal is accomplished by separating the end of the inner tube from the braid and using it as a lip seal in an annular chamber. Positive attachment to the hose is provided without the need for periodic adjustments. The hose lines are currently being produced in ½, ¾, and 1-in. sizes, and the range will be expanded. Made by **Aeroquip Corp.**, Jackson, Mich.

For more data circle MD-56, page 209

## Miniature Speed Changers

Redesigned Series 3 variable speed changers are now available with three different types of geared controls. The output shaft speed can be infinitely varied from



one-fifth to five times the input shaft speed by rotating the speed control shaft with either spur, miter or worm geared remote controls. Small and lightweight, the units are used for remotely controlled applications in recorders, flow controls, regulators and scanning mechanisms. The spur geared control may be used where the control shaft and the remote control shaft are parallel. A choice of mating spur gears offers a selection of control speeds. Made by **Metron Instrument Co.**, 432 Lincoln St., Denver 3, Colo.

For more data circle MD-57, page 209

## Roller Bearing

This self-aligning, torque tube, double-row roller bearing is factory-lubricated and equipped with

positive seals which retain lubricant and prevent air loss in pressurized aircraft. A high-capacity, lightweight bearing with minimum cross-section dimensions, it is designated the DP Series by **Shafer Bearing Corp.**, 801 Burlington Ave., Downers Grove, Ill.

For more data circle MD-58, page 209

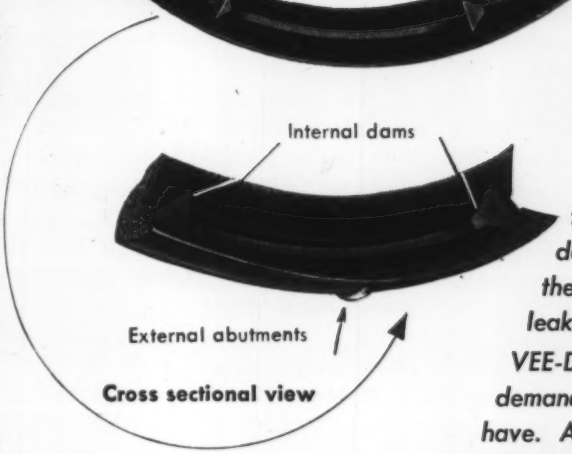
## Surface Bonded Lubricants

Three compounds, designated Surf-Kote H-108, H-110 and H-205, are colloidal dispersions of a modified molybdenum disulfide in various types of resinous binders. They may be applied, by spraying or dipping with usual paint and enamel equipment, to surfaces such as ferrous alloys, stainless steels, aluminum, brass and bronze, magnesium.

**Greatest Giant** in Lockheed Aircraft's "Hall of Giants" is this 8000-ton Birdsboro deep-draw press... the largest of its type in the world. Its big main rams, in keeping with their advanced design, are sealed with LINEAR VEE-DAM Rings, the most effective modern hydraulic packing ever developed!

## Foolproof to assemble
## Leakproof in operation

# LINEAR VEE-DAM RINGS




**Cross sectional view**

*The unique design of LINEAR VEE-DAM Rings makes possible, for the first time, a split "V" ring packing that is really leakproof . . . ideal for hydraulic presses, pumps and pneumatic equipment.*

*A look at the close-up view of a VEE-DAM Ring will tell you why they seal so effectively. Those sturdy rubber dams, faced in opposite directions, are moulded into the groove hinge area of the ring, completely eliminating leakage between rings.*

*VEE-DAM Rings are easier to install because they don't demand the precise fitting that ordinary rings should have. And they last longer, too, because they seal perfectly tight with a minimum gland load.*

*Made of a choice of fabric reinforced synthetic rubbers, LINEAR VEE-DAM Rings are individually engineered for your application. Write or call LINEAR for complete information.*

"PERFECTLY ENGINEERED PACKINGS"

LINEAR

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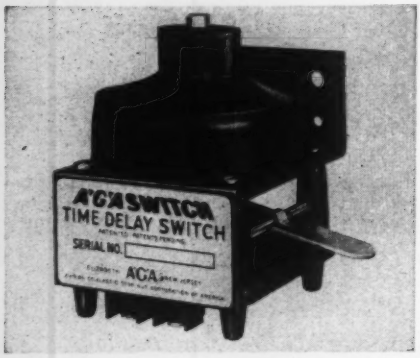
titanium, cadmium and zinc. They provide chemical resistance to oils, greases, solvents, acids and alkalis, depending on the compound used. Optimum operating temperatures range from 100 to 950 F. Developed by **Hohman Plating & Mfg. Inc.**, Dayton, O.

For more data circle MD-59, page 209

## Time Delay Switch

Operated by a lever, the Aga-switch has an adjustable delay from 0.1 second to more than 5 minutes. This delay is obtained by restricting air flow through an adjustable orifice in the timing head. The timing chamber is enclosed and dustproof, the air used

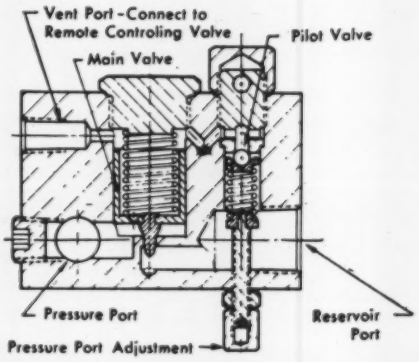



for timing being recirculated inside it. Unit is available in both single-pole double-break and double-pole single-break types for resistance loads of approximately 15 amp at 115 v and 60 cycles. It measures 2½ in. square and 3-in. high. Made by AGA Div., **Elastic Stop Nut Corp. of America**, 1027 Newark Ave., Elizabeth 3, N. J.

For more data circle MD-60, page 209

## Relief Valve

When it is not practical to place a standard relief valve in normally accessible location or near other machine controls, this remotely operated pilot type can be used. Unit has internal pilot valve which is set at maximum rating of pump or machine, plus provision for connecting one or more external pilot valves. Relief pressure is constant and little affected by flow, temperature or oil viscosity. No warm-up

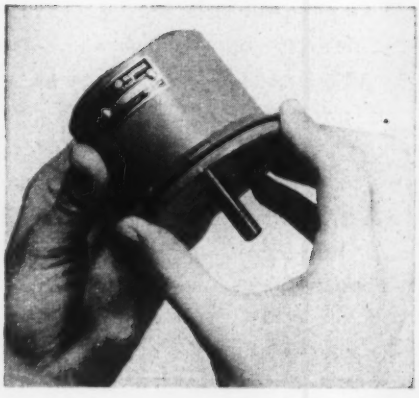



time is required, and cracking pressure is 90 per cent or more of maximum relief pressure. Made by **Fluid Controls Inc.**, 1284 North Center St., Mentor, O.

For more data circle MD-61, page 209

## Magnetic Tension Brakes

By providing constant tension, two new magnetic tension brakes of the hysteresis type reduce abrasion and excess flexing of yarns, rubber, glass fiber and wire in winding processes. Torque ranges of 0.4 to 4.0 and 2.0 to 14.0 oz-in. supplement original line which has torque range of 0.1 to 0.5-oz-in.

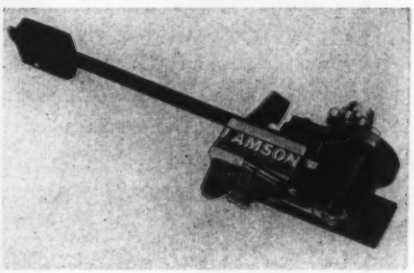


Brakes are about 2 and 3 in. diameter, weigh about ¾ and 2½ lb, respectively, and have a speed range of 0 to 1500 rpm. Turning the calibrated aluminum magnet housing decreases or increases the brake torque. Brake holds stalled tension by a tendency to reverse direction of rotation for a few degrees after decelerating to a standstill. Units retain required torque unaffected by lint, moisture and heat. Made by **General Electric Co.**, Schenectady 5, N. Y.

For more data circle MD-62, page 209

## Overload Protector

Consisting of an eccentrically located sprocket counterbalanced by a weighted arm, this chain overload protector can be adjusted to operate at any chain tension up to 1000 lb. Manual resetting is required after the device has been

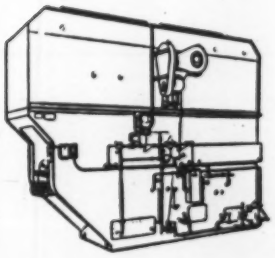



tripped before drive can become operative again. With an eccentric sprocket shaft of 0.875-in. diameter, unit can be adapted to chain sizes from ½ to 1¼ in. Basic applications are single and double sprocket vertical, double sprocket rotary and single sprocket horizontal chain drives. Made by **Lamson Corp.**, Syracuse 1, N. Y.

For more data circle MD-63, page 209

## Subminiature Blower

Capable of delivering 3 cfm, the Minicube subminiature blower is a 1-in. cube weighing 1 oz, including motor and blower housing. Use is for circulation of air and cooling of electronic parts and equipment. It can be installed in hermetically sealed equipment for heat transfer to or from the case. Standard models operate in range from



DEGREASING MACHINE

# what are your VALVE NEEDS?

AIR VISE

Do you have a space limitation to deal with before you select a valve? Is delivery of the automatic valves you're now using slowing down production?

If you have a pressure control valve need, here's how to fill it. The answer lies in a CASH-ACME valve . . . Or with CASH-ACME's staff of engineers who will develop just the valve to do the job you have in mind.

Mail the coupon below with a brief outline of your installation requirements. A free booklet or catalog on request.

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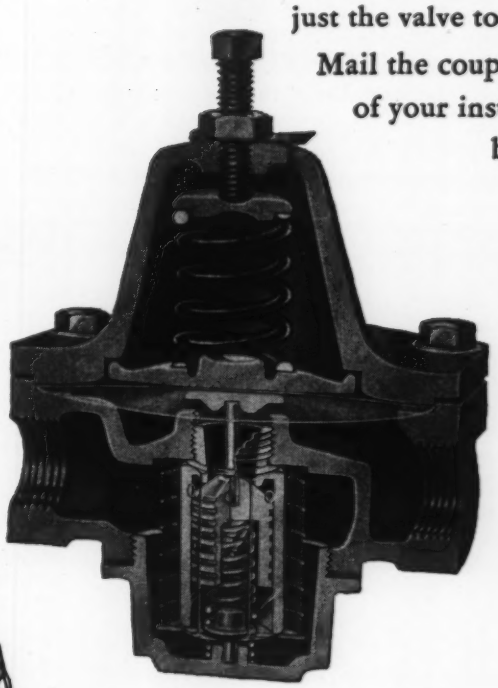
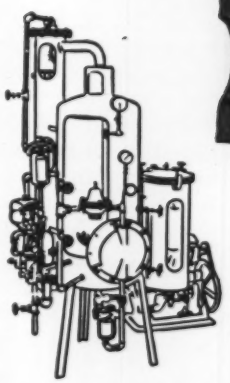


## cash-acme has the ANSWER!



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SILENT SENTINEL *Automatic Valves*

**A. W. CASH VALVE MFG. CORP.**
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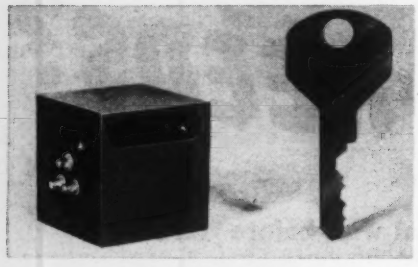
−55 to 85 C, with life of 1000 hr. Other models have wider temperature ranges. Motor turns at speed of 24,000 rpm and is supplied for operation on 6.3 v, 3-w or 26 v, 4-w, 400-cycle operation. Made by **Sanders Associates Inc.**, Nashua, N. H.



For more data circle MD-64, page 209

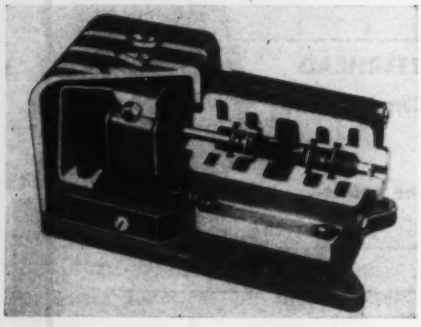
## Wire Braid Air Hose

Flexible, heavy-duty Commander hose can be used with working pressures up to 400 psi. Hose cover will withstand severe abrasion. Oil-resistant hose tube permits oiling of tools through the hose. Manufactured in ½, ¾ and 1-in. sizes by the **B. F. Goodrich Co.**, Akron, O.

For more data circle MD-65, page 209

## Solenoid Air Valve

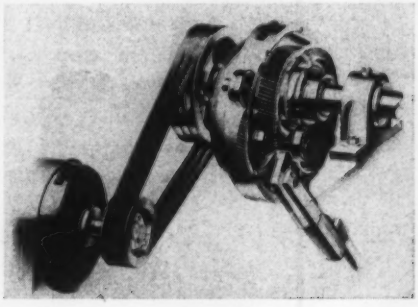
Design of improved solenoid operated air valve incorporates an aluminum alloy, surface hardened spool on which the sealing material is integrally molded and bonded. Seals enter the bearingized bores of body and retainers to effect a "sealed with air pressure" seal. Featherlight contact of seal contributes to long life. Mechanical and electrical construction is simple and accessible. Valves have full pipe orifice area with maximum straight-through flow. Made by **Mechanical Air Controls, Inc.**, 15311 West Eleven Mile Rd., Detroit 37, Mich.



For more data circle MD-66, page 209

## Speed Reducer

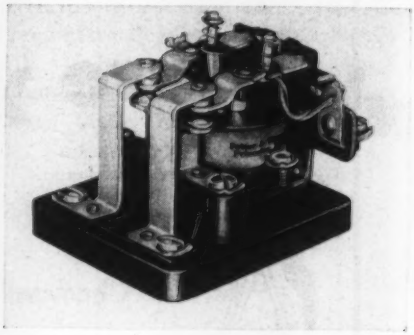
Shaft-King 13-to-1 ratio shaft-mounted speed reduction units, which retain features of the original 20-to-1 series, are adaptable to any shaft size up to 3 15/16 in. V-belt drive type units are compact, requiring only standard shaft lengths (twice the shaft diameter plus clearance) to be mounted directly on the shaft of the driven machine. Gearing and bearings are splash lubricated. Both input and output shaft are above the oil level, eliminating the necessity for bearing seals to operate against a head of oil. For protection against sudden overloads, reducers can be equipped with American torque-arm overload release. Made by **American Pulley Co.**, 4200 Wissahickon Ave., Philadelphia 29, Pa.



For more data circle MD-67, page 209

## Heavy-Duty Relays

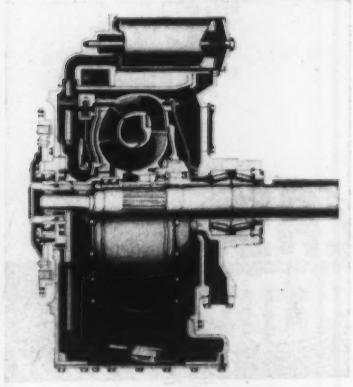
Redesign of PR line of heavy-duty power relays assures complete insulation for severe service. Mounting dimensions of plastic base relays are same as metal base units. Model 11 relay, illustrated, as well as models 4 and 8 have insulating barrier molded to base between the stationary contacts. Ratings and coil voltage are unchanged from previous metal base units. Made by **Potter & Brumfield**, 1200 East Broadway, Princeton, Ind.



For more data circle MD-68, page 209

## Two-Stage Torque Converter

Meeting requirements of engine applications needing converter drive with specific performance characteristics, this hydraulic converter develops up to 4:1 torque multiplication at stall and produces progressively increasing engine speed during acceleration and uniform pull-down under load. Freewheel reaction, or stator, blades provide complete unloading of the engine at high-speed, no-load conditions—with low horsepower absorption for economy, and with minimum cooling requirements. Model S offers a standard spider drive input and is equipped with a built-in converter charging pump

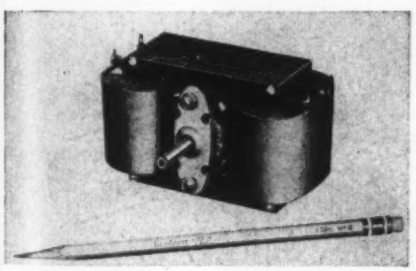


around the input shaft. Inlet and outlet connections are provided for piping the converter fluid to and from a cooler, which can be either an oil-to-water heat exchanger or an oil-to-air radiator. Either straight extension or flanged output shafts are available. The converter is also offered in a disconnecting type, Model SD, which is small and features quick-release dump valves on the rotating turbine wheel, and a two-position control valve located on top of the stationary converter housing. Manufactured by **Twin Disc Clutch Co.**, Hydraulic Div., Rockford, Ill.

For more data circle MD-69, page 209

## Miniature Motors

Approximately half the size and weight of conventional two-pole motors of equal power rating, these motors are offered in 1/30

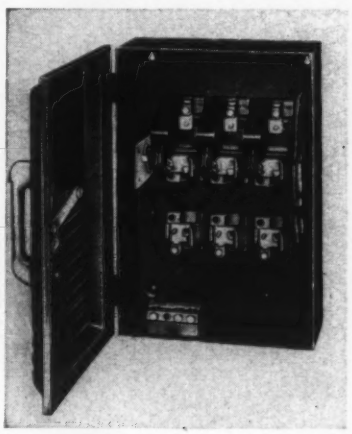


to ⅛-hp sizes. Shafts are centered rather than offset, and the motors can be used in geared-down and pulleyed-down applications. The 1/10-hp motor measures approximately 2¼ by 4¼ by 2¼ in. and weighs about 4 lb. Manufactured by **Burgess Vibrocrafters Inc.**, 180 North Wabash Ave., Chicago 1, Ill.

For more data circle MD-70, page 209

## Industrial Safety Switch

Noark 200-amp switch features space-saving front operation and an oversize handle that shows from a distance whether the switch is on or off. Switch is one of a line which also includes 30, 60 and 100-amp models for use in 250 and 600-v lines. Fuse holder has a pressure spring located under the fuse where it is unaffected by fuse heat. Only two joints are used on each pole, providing cool operation. Insulated cross bar fitted underneath the switch insures opening when the handle is thrown to the

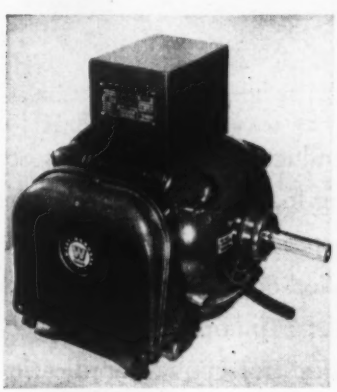


off position. Made by **Federal Electric Products Co.**, 50 Paris St., Newark, N. J.

For more data circle MD-71, page 209

## Single-Phase Motor

Operating efficiently at near-unity power factor, type CAP-2 single-phase motor is made in 5, 7½ and 10-hp ratings. Design retains high starting torque, and at the same time reduces starting current by about 25 per cent.

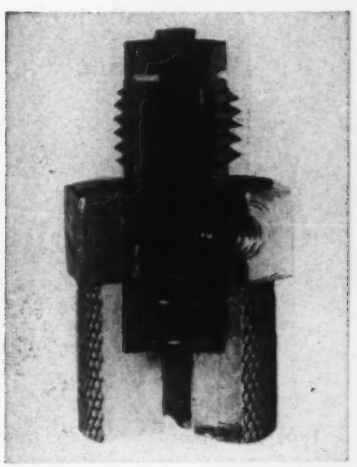


Auxiliary winding remains in the circuit during operation and is in series with the running capacitors. Relays merely remove the starting capacitors when motor approaches full speed. Elimination of the wound rotor, brushes and commutator of the previous repulsion-induction type makes for a simpler unit with less maintenance. Sparking is also eliminated. Made by **Westinghouse Electric Corp.**, P.O. Box 2099, Pittsburgh 30, Pa.

For more data circle MD-72, page 209

## Bleeder Valve

Semiautomatic in operation, this bleeder valve is adaptable to both hydraulic and pneumatic lines of any size or pressure. It is spring-loaded, using a channeled knife-edged cap that uncovers the bleed



port with a twist of the external head. Outlet port is threaded for installation of a hose or tube. Internal O-ring prevents leakage around the connecting shaft. Made by **Greer Hydraulics, Inc.**, 454 Eighteenth St., Brooklyn 15, N. Y.

For more data circle MD-73, page 209

## Air Pump

Dri-Air pump eliminates oil vapor and is used for operations requiring clean, dry air, in a rapid copious blast, or a vacuum. Precision-built, the pump has a balanced rotor which is fitted to close tolerances and requires no gas-

(*Continued on Page* 228)

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*for general purpose applications with high starting torque*

Type RK Motors
⅙ to 5 hp.

Wagner capacitor-start induction motors are a sound choice for applications where starting loads are fairly heavy, but which can be brought up to operating speed quickly. They have become increasingly popular for installation on equipment such as air conditioners, refrigerators, freezers, water pumps, motor-driven tools, and on similar fractional or integral horsepower applications.

These motors offer low maintenance cost—only a minimum of servicing is required—and they give many years of reliable service with unusual freedom from vibration and noise.

M58-12

These motors are available in frames 225 and smaller, in open or totally-enclosed types—sleeve or ball bearing, with rigid or resilient bases or machined endplates for flange mounting. Frames are formed of heavy rolled steel. The rotor squirrel-cage is of aluminum, cast under pressure. Type RK capacitor-start induction motors feature steel-backed babbitt lined bearings, roomy oil wells packed with long strand wool yarn, and dependable quick make-and-break switches which have proved their ability in service.

When you standardize on Wagner Motors—you get the advantages of a liberal warranty . . . of nationwide service facilities, with on-the-spot service, replacement motors and parts available from 25 Wagner-owned Service Branches and more than 750 Authorized Service Stations. You can choose from a wide variety of types and sizes—single-phase or polyphase—(from 1/125 to 400 hp). Bulletin MU-185 gives complete information—write for your copy.

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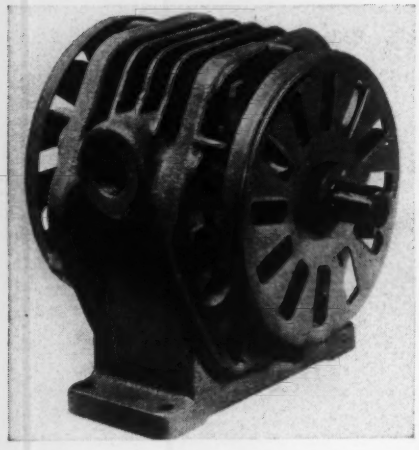
(*Continued from Page 225*)

kets. The rotor is mounted on two double-sealed, grease-packed ball bearings. The special-alloy vanes are hard, light, nonsticking, nonwarping and chemically inert. They

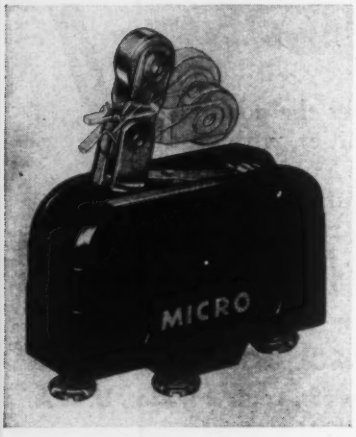


require no lubrication. Made by **Conde Milking Machine Co. Inc.**, Sherrill, N. Y.

**For more data circle MD-74, page 209**

## Snap-Action Switch

Designed for one-way actuation by a cam, dog or slide, the switch has a spring-loaded, hinged roller arm actuator. Available with either 3/16 or 3/8-in. diameter roll. Both




models have either solder lug terminals or screw terminals. Ratings are 15 amp at 125, 250 or 460 v ac; ½ amp at 125 v dc; ¼ amp at 250 v dc. Made by Micro Div., **Minneapolis-Honeywell Regulator Co.**, Freeport, Ill.

**For more data circle MD-75, page 209**

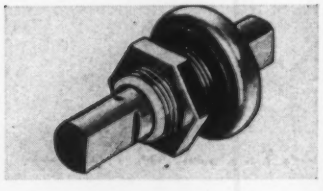
## Oil-Resistant Belting

Supertex HC incorporates a Hycar acrylonitrile synthetic rubber cover on a carcass of Neoprene WRT belting, which is highly resistant to vegetable oils. The new conveyor belt is white, has a smooth cover and is available in widths up to 48 in. It can be vulcanized endless. Made by **Baldwin Belting Inc.**, 483 Washington St., New York 13, N. Y.

**For more data circle MD-76, page 209**

## Rotary Shaft Seal

Designed to pressure seal, waterproof and moisture seal panel mounted shafts in such equipment as hand-operated electrical circuit and tuning mechanisms, series 1100 rotary shaft seals do not require lubrication. Design combines the flexibility and sealing quality of

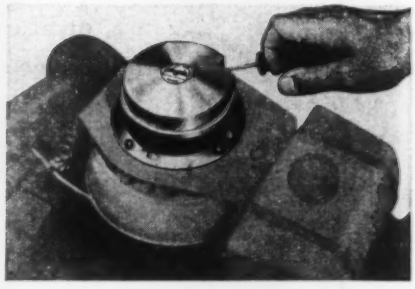


rubber, low friction resistance of metal against bearing material and corrosion resistance. Shafts are in one piece to eliminate backlash. Three standard sizes are available. Made by **H. H. Buggie Inc.**, 726 Stanton St., Toledo 4, O.

**For more data circle MD-77, page 209**

## Rewind Starter

For use on lawn mowers, chain saws and similar gasoline engine-equipped products, Bulldog starter applies friction on the inside of conventional starter cup. Starter is cam-actuated, and engages after ¼-in. pull on the starter rope. Assembly does not require

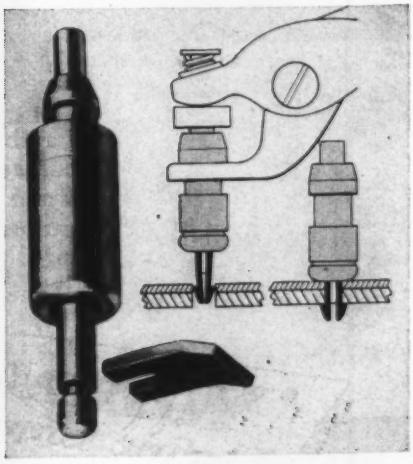


close-tolerance assembly and is unaffected by flooding with water, oil, or gasoline. It is available for incorporation in original equipment with or without housing and various grass and chip guards. Made by **Armstrong Products Co.**, 6450 North Teutonia Ave., Milwaukee, Wis.

**For more data circle MD-78, page 209**

## Sheet Metal Fasteners

Metal or hard surface parts containing drilled or punched holes can be temporarily held together in alignment and under pressure by Wedgelock quick-acting sheet metal fasteners. Combined materials up to 4 in. thick can be held in place during drilling, riveting, fabrication and assembly. Application is



from one side. Both spring-actuated and hand-operated wing nut types are made in a variety of sizes

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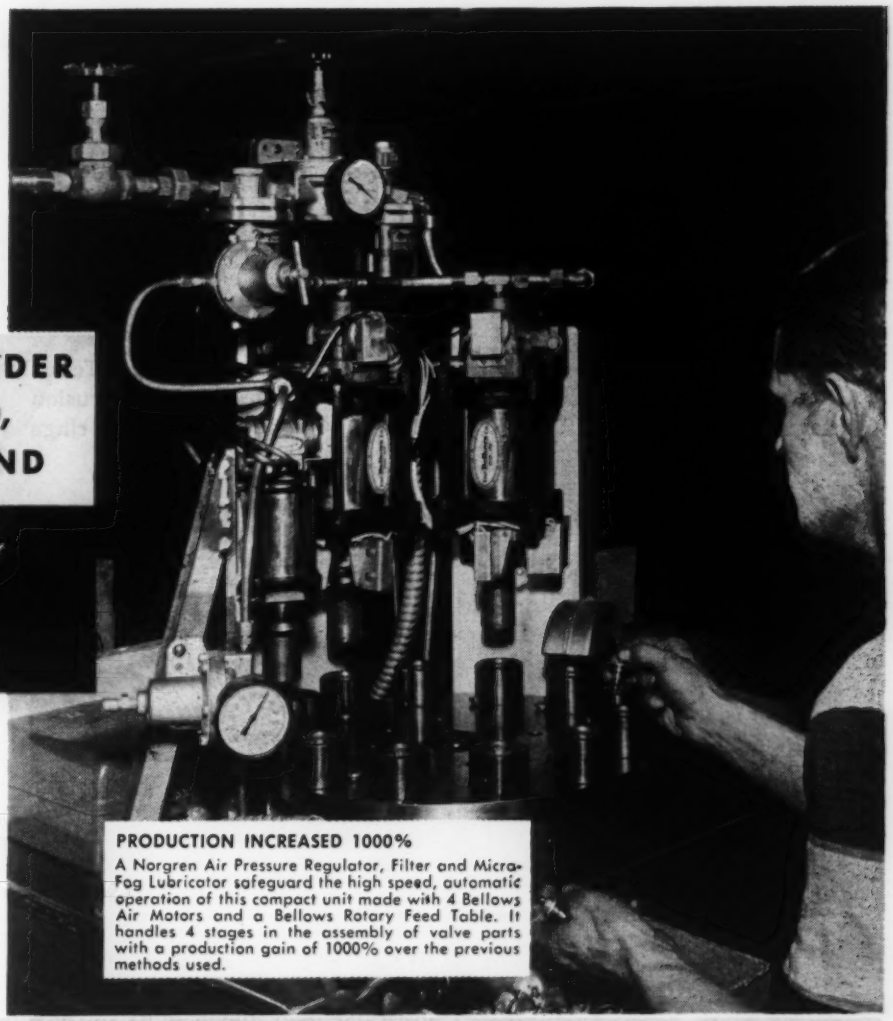
**to assure best lubrication**



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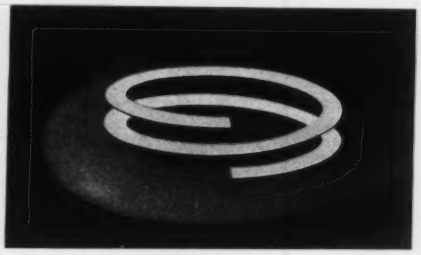
and capacities for reuse. Made by **Wedgelock Co.**, 5446 Satsuma Ave., North Hollywood, Calif.

For more data circle MD-79, page 209

## Back-Up Rings

Spirally machined from Teflon and designed to prevent extrusion of O-ring seals, these back-up rings



have high impact strength at temperatures from −100 to 500 F. They are also noncorrosive, nonfraying and are self-lubricating and inert to most chemicals. They are made for all O-ring sizes to AN drawings 6227 and 6230 by **Garlock Packing Co.**, Dept. 34, Palmyra, N. Y.

For more data circle MD-80, page 209

## Position Indicator

Doelcam Microsyn electromechanical signal generator transforms angular displacement into an electrical signal for measurement of any mechanical variable. With

an appropriate feedback system, the indicator may be used to control industrial processes. Features linear output resolution to 1/100 degree, negligible reaction torque and sensitivity up to 7 volts per degree at 40 cycles per second. Made by **Doelcam Corp.**, Soldiers Field Rd., Boston 35, Mass.

For more data circle MD-81, page 209

## Plastic Valves

Vanilene plastic globe and Y valves are corrosion resistant and will withstand most acids as well as a variety of caustic solutions. Fabricated from polyethylene, they are light in weight, high in

strength, and are recommended for working pressures up to 50 psi and temperatures to 150 F. Available in ½, 1, 1½ and 2-in. sizes. Made by **Vanton Pump Corp.**, Empire State Bldg., New York 1, N. Y.

For more data circle MD-82, page 209

## V-Belt Pulley

Flanged type split taper bushing permits hub of QD Junior fractional horsepower V-pulley to grip shaft and still allows easy assembly and removal. Two-piece assembly is drawn together by three slotted hex-head machine screws, using either wrench or screwdriver. Additional tapped holes permit use of assembly screws as jack screws to break the cone grip. A common hub is used for complete pulley range, which is from 3.5 to 15.4-in. diameter. Bore range is from ½ to 1¼-in. by 1/16-in. increments. Made by **Worthington**

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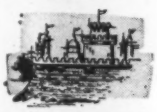
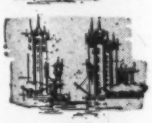


Metallgesellschaft, A. G., Germany — **26** years



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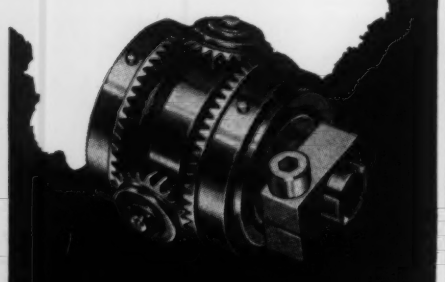

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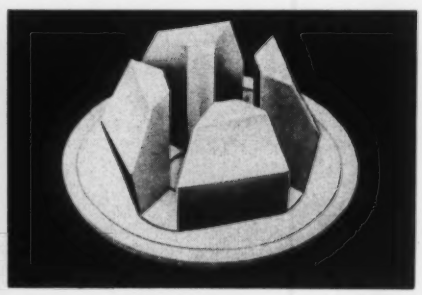
Corp., Mechanical Power Transmission Div., Oil City, Pa.

For more data circle MD-83, page 209

### Plastic Hole Plugs

Round or square holes ranging from $\frac{1}{8}$ to over 1-in. diameter in assembled products from autos to household appliances can be closed up by these plastic hole plugs.

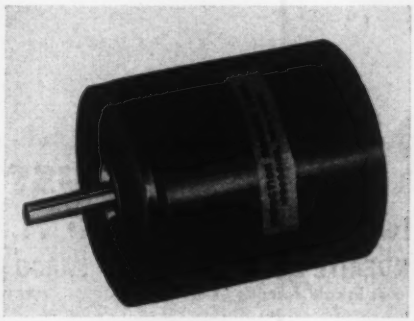


Easily pressed into position with only the fingers, plugs provide a moistureproof seal. They are available in wide choice of colors for matching purposes. An example of their application is the sealing of holes in inner liners of refrigerators to prevent air circulation between walls. Made by Shakeproof, Div. of **Illinois Tool Works**, 2501 North Keeler Ave., Chicago 39, Ill.

For more data circle MD-84, page 209

### Servo Motors

Designed for applications requiring light weight and exact performance, low-inertia Models 1300 and 1500 are available for two phases, 60 to 400-cycle frequency, in 2, 4, 6 and 8-pole construction. They can be supplied with high impedance control winding for plate-to-plate operation and can be specially built to meet specification. Made by **Induction Motors Corp.**, 55-15 37th Ave., Woodside 77, N. Y.



For more data circle MD-85, page 209

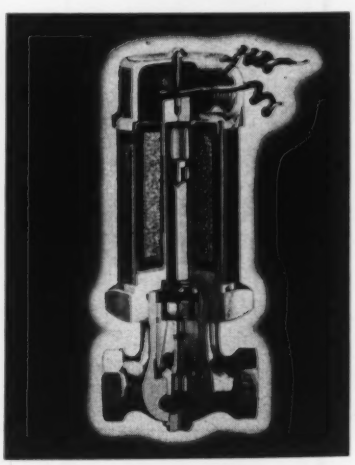
### Cushioned Jewel Mountings

Protection against stresses of vibration, shock and improper adjustment is provided by these cushioned jewel mountings for jewel assemblies. Resilient cushion of silicone rubber absorbs shocks and vibration and is capable of withstanding temperatures from −85 to 325 F. Application can be in delicate instruments and meters exposed to extreme conditions. Made by **Richard H. Bird & Co. Inc.**, Waltham, Mass.

For more data circle MD-86, page 209

### Steam Valve

This valve is designed to operate without sticking, which is caused by valve expansion at high temperatures combined with deposits of iron oxide, boiler compound, lime, etc. Increased clearance between the piston and cylinder walls compensates for normal steam valve expansion and deposits. Made by **Atkomatic Valve Co.**, 545 Abbott St., Indianapolis 25, Ind.



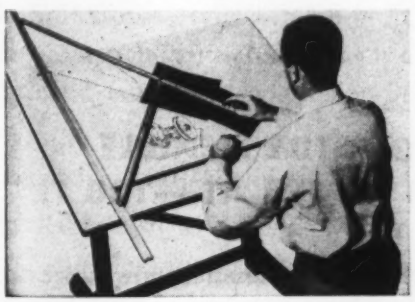
For more data circle MD-87, page 209

ENGINEERING DEPARTMENT

# EQUIPMENT

## Drawing Instrument

The Adapto-Arm produces pictorial drawings in isometric, dimetric and trimetric by tracing the normal orthographic views of the object. The instrument has three moving parts—the 52-in. channel track, which can be secured to the drawing table; the marking link, and the tracing link. A runner is



attached at one end of each link for the purpose of sliding freely in the channel track. The tracing link and the marking link are pivoted 24 in. from the runners. Slots in each link provide means of fastening marker and tracer. Made by the **Wilkinson Co.**, P. O. Box 638, Arnold, Md.

**For more data circle MD-88, page 209**

## Oscillogram Processor

Oscillographic records on any standard recording papers up to 12 in. in width may be completely processed and dried at speeds exceeding 10 fpm by the 23-109 Oscillogram Processor. Processing is accomplished without darkroom facilities or an external water supply. Measuring 17 in. wide, 31 in. long, 18 in. high, the unit may be carried directly to a test site to

(*Continued on Page 240*)

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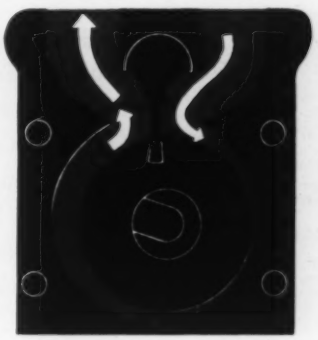
has specialized for years in the design and manufacture of small, low cost, positive displacement, pumps for original equipment on many types of machines, devices and appliances.



- **Eco Pumps' axially-oscillating dual-impeller action permits smaller motors using less power.**
- **Internal constructions are available in a wide range of materials—metals, plastics, rubber—for pumping all types of clear fluids.**
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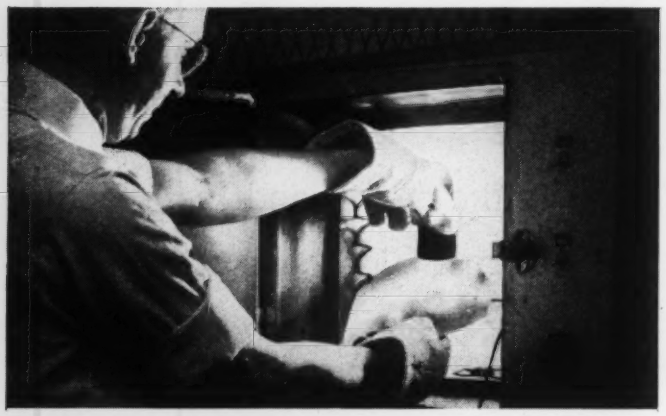
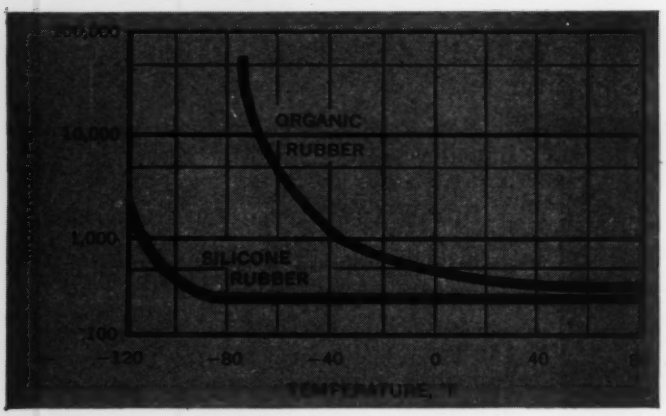
# NEW SILICONE
## DEMONSTRATED BY TEST...



**High temperature resistance:** Elevated temperatures have no appreciable effect on the 1000-1200 volts per mil dielectric strength of glass cloth coated with SE-100.

### SE-100—IDEAL FOR ELECTRICAL AND MECHANICAL APPLICATIONS!

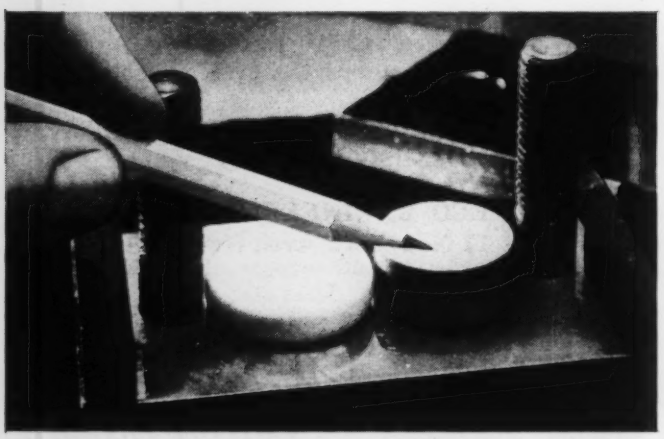
**General Electric's new silicone rubber coating compound, SE-100,** combines outstanding heat resistance, electrical and physical properties for a wide variety of electrical and mechanical applications. SE-100 may be coated on glass or organic fabrics for service at high or low temperatures or where resistance to weather, ozone, corona or chemicals is required.




**Flexible at −120 F:** A glance at the blue curve shows the difference (Young's Modulus in flexure) of SE-550 versus organic rubber after 24 hours.

### SE-550—STILL FLEXIBLE AFTER 24 HOURS AT −120 F!

**G. E.'s new extreme low-temperature silicone rubber, SE-550,** combines high strength and elongation with maximum low-temperature usefulness. SE-550 shows practically no increase in modulus at −100 F and retains useful flexibility at −120 F. This flexibility is achieved without sacrifice of high-temperature resistance or any of the other desirable properties inherent in silicone rubber.



**Compression test:** Same-size pieces of ordinary silicone rubber and SE-360 are compressed for 22 hrs. at 350 F. Note how SE-360 (right) "comes back" to original size.

### SE-360—MORE "COME BACK" THAN ANY KNOWN RUBBER!

**G. E.'s new low compression set silicone rubber, SE-360,** is designed to provide more positive sealing action in parts subject to compression at elevated temperatures. In addition to its outstanding low compression set, SE-360 has unusually low shrinkage when cured. This means parts with more uniform properties, closer tolerances and opportunities for your fabricator to cut scrap loss.

# ELLIOTT CROCKER-WHEELER

Gives you the speed you want, where you want it—

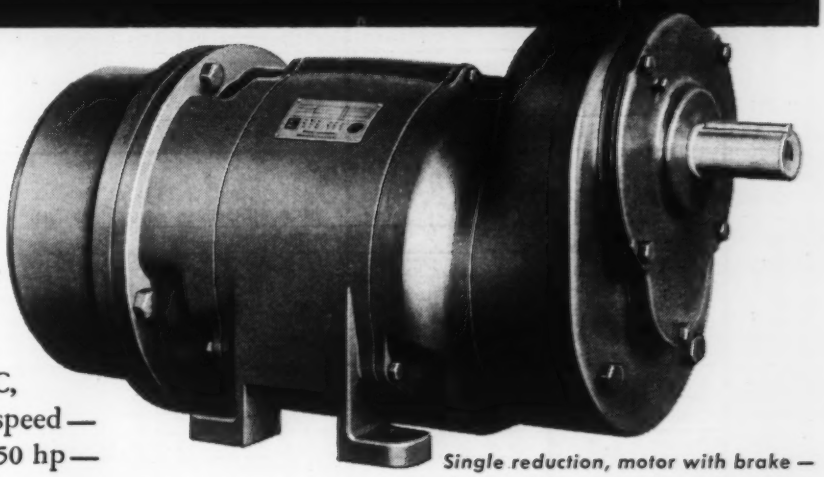
In single reduction, 780 to 280 rpm . . . double reduction, 230 to 45 rpm . . . triple reduction, 37 to 7.5 rpm—

With any Crocker-Wheeler Motor—AC, squirrel-cage, wound rotor, DC, multi-speed—in the range of frame sizes from 1 to 150 hp—

In any closure type—open-protected, enclosed non-ventilated, splashproof, enclosed fan-cooled, explosion-proof—

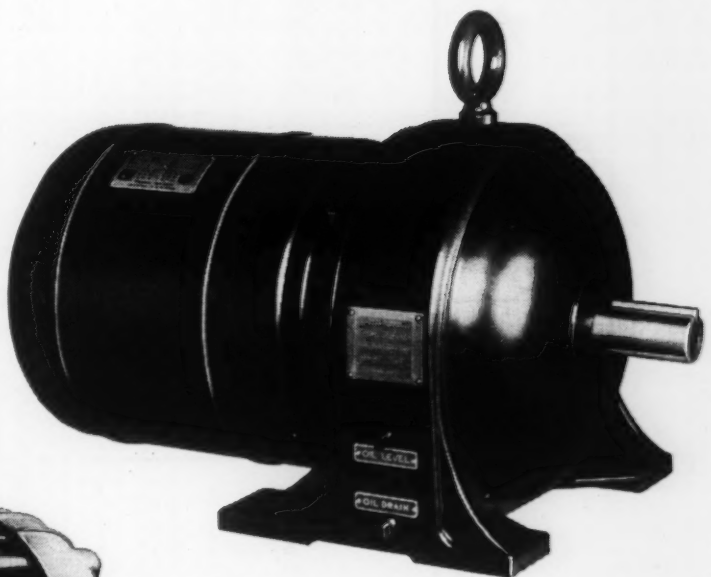
For any mounting required—horizontal, ceiling, sidewall, inclined—

Available also with the C-W disc brake, as a complete integral power unit—

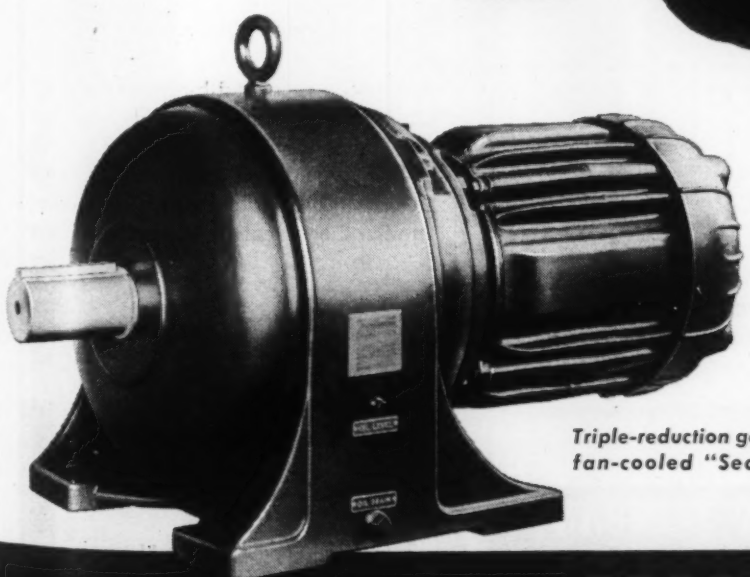


*Single reduction, motor with brake—A complete integral power unit—*

**GET THE GEARMOTOR DATA BOOK**
—ask your local Elliott District Office or write direct to Elliott Company, Crocker-Wheeler Division, Ampere, N. J.



*C-W Form BA squirrel-cage motor with double-reduction gear—*



*Triple-reduction gear unit mounted on C-W totally-enclosed fan-cooled "Sealedpower" explosion-proof motor—*

**ELLIOTT Company**
CROCKER-WHEELER DIVISION

# INDEX OF ACP CHEMICALS FOR METAL PRESERVATION AND PAINT PROTECTION

| METAL | OPERATION | ACP CHEMICAL |
|---|---|---|
| ALUMINUM | Cleaning | "DEOXIDINE"<br>"DURIDINE"<br>"ACP RIDOLINES AND RIDOSOLS" |
| | Preparation for Painting | "ALODINE"<br>"DURIDINE"<br>"DEOXIDINE" |
| | Protection from Corrosion | "ALODINE" |
| GALVANIZED IRON, ZINC, AND CADMIUM | Cleaning | "DURIDINE"<br>"ACP RIDOLINES AND RIDOSOLS" |
| | Corrosion Proofing | "ZINODINE" |
| | Paint Bonding | "ZINODINE" |
| | Phosphate Coating, in Preparation for Painting | "LITHOFORM" |
| | Soldering Flux | "FLOSOL" |
| STEEL | Chromate Coating, in Preparation for Painting | "CROMODINE" |
| | Cleaning | "ACP RIDOLINES AND RIDOSOLS" |
| | Cleaning for Painting | "DEOXIDINE"<br>"DURIDINE" |
| | Coating with Copper | "CUPRODINE" |
| | Drawing and Extrusion | "GRANODRAW" |
| | Paint Bonding | "CROMODINE"<br>"DURIDINE"<br>"GRANODINE"<br>"PERMADINE"<br>"THERMOIL-GRANODINE" |
| | Paint Stripping | "CAUSTIC SODA AND SOLVENT NO. 3" |
| | Phosphate Coating, in Preparation for Painting | "DURIDINE"<br>"GRANODINE"<br>"PERMADINE"<br>"THERMOIL-GRANODINE" |
| | Phosphate Coating, to Protect Friction Surfaces | "THERMOIL-GRANODINE" |
| | Pickling with Inhibited Acids | "RODINE" |
| | Rust Prevention for Unpainted Iron | "PEROLINE" |
| | Rust Proofing | "PERMADINE"<br>"THERMOIL-GRANODINE" |
| | Rust Removal—Brush, Dip, or Spray | "DEOXIDINE" |
| | Soldering Flux | "FLOSOL" |

*Visit Our Display in*
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*Main Exhibition Hall*
*Cleveland*
*Public Auditorium*
*at the*
*National Metal Exposition*
*October 19th - 23rd*

CHEMICALS ACP PROCESSES

**AMERICAN CHEMICAL PAINT COMPANY**

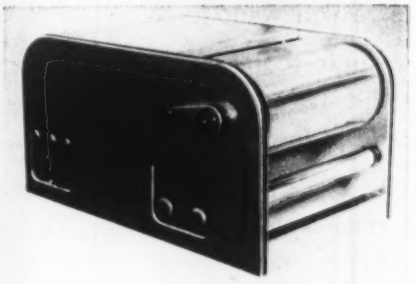
GENERAL OFFICES: AMBLER, PENNSYLVANIA

Detroit, Michigan  Niles, California  Windsor, Ontario


## Engineering Equipment

(*Continued from Page* 235)

provide data immediately following a test run. The 250-ft capacity magazine may be loaded in subdued light or a darkroom, depending on the sensitivity of the record material being used. Several magazines may be loaded at one time. Solutions are contained in stainless steel tanks and thermostatically maintained at 100 F to minimize ambient temperature effects.

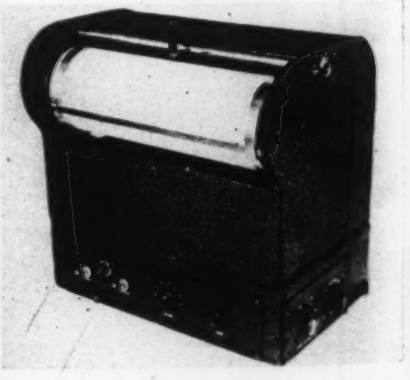


Drying-drum temperature is thermostatically controlled and may be adjusted by the operator for various humidity conditions, paper widths, and record materials. Models are available for operation from 115-v or 230-v single-phase ac lines from **Consolidated Engineering Corp.**, 300 North Sierra Madre Villa, Pasadena 8, Calif.

**For more data circle MD-89, page 209**

## Stress-Strain Recorder

Load is recorded by movement of the stylus parallel to the axis of the recorder drum; the stylus is driven by direct mechanical connection to the load-indicating element of the testing machine. Two



SKINNER ELECTRIC VALVE DIV.
115 Edgewood Ave.
New Britain, Connecticut

## Please Help Us...

We would like complete data on the Skinner Valves checked below:

☐ V10 ☐ V61 ☐ V2 ☐ V5-2
☐ V5-3 ☐ V9 ☐ V50 ☐ M3
☐ M2 ☐ X5

☐ Send full information on valves for _____

Name _____
Company _____
Street _____
City _____ State _____
☐ Have salesman call (approx.) date _____

Attach to Company Letterhead

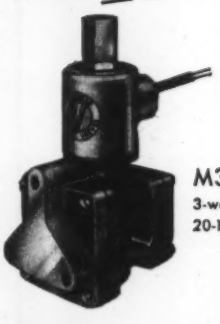
you will find the modern approach to your SOLENOID VALVE problems...

# SKINNER VALVES GUARANTEE

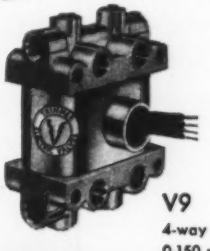
## MILLIONS of CYCLES

*(on most applications)*

The measure of performance in an electric valve is in *cycles*—millions of them in Skinner Valves... with the kind of guaranteed performance made possible through the constant research, lab testing and design facilities, know-how of Skinner engineers and the productive capacity of an ultra-modern plant. Skinner Solenoid Valves have a record of *satisfactory* and *dependable performance* in countless installations for gaseous or liquid control. Many models are Underwriters' Approved. Let us approach your problem in the modern manner. Some of the many Skinner Valves are shown below.



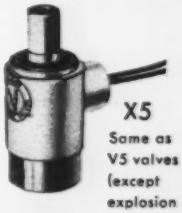
**M3**
3-way
20-150 p.s.i.



**V9**
4-way
0-150 p.s.i.

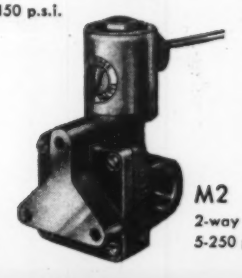
**V61**
2-way
0-300 p.s.i.

**V5-2**
2-way
0-1000 p.s.i.

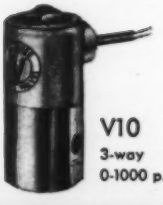


**X5**
Same as V5 valves (except explosion proof)
0-300 p.s.i.

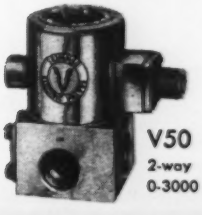
**V2**
2-way
0-200 p.s.i.



**M2**
2-way
5-250 p.s.i.



**V10**
3-way
0-1000 p.s.i.



**V50**
2-way
0-3000 p.s.i.

**V5-3**
3-way
0-300 p.s.i.

SKINNER SOLENOID VALVES

**SKINNER ELECTRIC VALVE DIV., The Skinner Chuck Company, 115 Edgewood Ave., New Britain, Connecticut**

SHOCK – VIBRATION – NOISE

# ISOLATION NOTES

*These* **NEW** *Product Bulletins give* **YOU**

## COMPLETE ENGINEERING DATA on ALL-METL BARRYMOUNTS

*Here's what's in them for* **YOU:**

1. Transmissibility curves showing performance under test conditions of JAN-C-172A.
2. Curves showing reduction of transmitted acceleration and displacement.
3. Curves showing how changes in loading affect transmissibility at resonance and natural frequency for vertical motion.
4. Curves showing effect of high and low temperature on isolator performance.
5. Shock-characteristic data, including curves showing vibration isolation after 15g shock test.
6. Application data, including curves that show you how to choose isolators for unsymmetrical loads.
7. Dimensioned drawings of unit isolators, channel pairs, and mounting bases.
8. Detailed data on the construction, operating principle, and weights of mounts and bases.
9. A complete list of load ratings and catalog numbers for unit isolators, channel pairs, and bases.

These are the first really comprehensive bulletins on knitted-wire vibration isolators. To get your FREE copies, ask for Barry Product Bulletins 534 and 536. *And, if you have a special problem, count on getting the right answer from our Field Engineering Service.*

THE **BARRY** CORP.

**722 PLEASANT ST., WATERTOWN 72, MASSACHUSETTS**

SALES REPRESENTATIVES IN

Atlanta Baltimore Chicago Cleveland Dallas Dayton Detroit Los Angeles Minneapolis New York Philadelphia Phoenix Rochester St. Louis San Francisco Seattle Toronto Washington

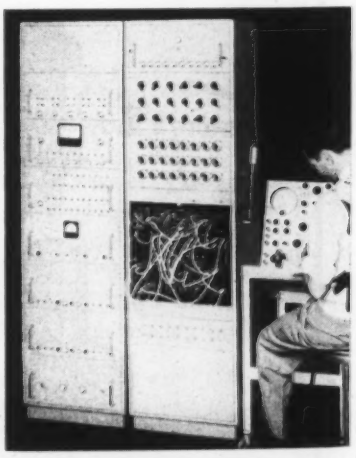
## *Engineering Equipment*

recorder load ranges are available for each indicator range, one providing full recorder scale for 50 per cent and the other for 100 per cent of each indicator range. Strain is recorded by rotation of the drum, which is driven through reduction gears by an electric motor controlled by two opposed balancing electromotive forces. The recorder is also provided with adapters which permit recording the output of SR-4 strain gages attached directly on the surface of test specimens. The equipment operates on 50-60 cycle, 110-v power. Accuracy of strain measurements is 0.2 per cent of the recorder range or 0.5 per cent of reading. Made by **Baldwin-Lima-Hamilton Corp.**, Philadelphia 42, Pa.

For more data circle MD-90, page 209

## *Analog Computer*

Electronically simulating various physical systems, the EASE analog computer can operate as an equation solver, a system analyzer or a design instrument. Empirical or theoretical formulas for a system under study are set up on the



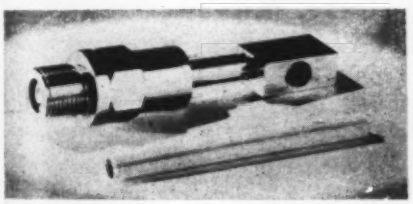
computer, and the problem is solved by varying coefficient potentiometers. To extend the capacity of the unit to solve more complex problems, components may be added by inserting them into the rack and applying power. Function and operational relays are provided, enabling the unit to

operate in real time, fractions of real time, or on a repetitive rate basis. Computers are available in 10, 20 or 30-amplifier sizes from Berkeley Scientific Co. Div., **Beckman Instruments Inc.**, 2200 Wright Ave., Richmond, Calif.

For more data circle MD-91, page 209

## Pressure Pick-Up

Expected to find use in current research activities on rocket propellants and jet engines, this device has a stainless steel diaphragm which can be exposed to gas temperatures in excess of 5000 F without damage. The heat-transfer rate

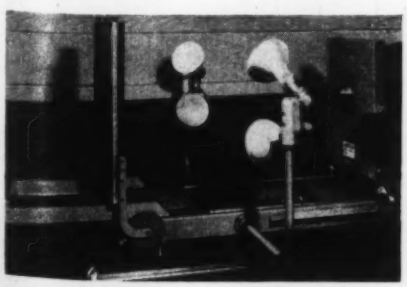


for the entire face of the unit is 11 Btu per square inch second with a cooling water temperature rise of 85 F. All exposed parts are made of stainless steel. The small size instrument is made by **Control Engineering Corp.**, 560 Providence Highway, Norwood, Mass.

For more data circle MD-92, page 209

## Copying Camera

The No. 4 Lith-Master copying camera has automatically controlled exposure speed and lighting. The camera copies material up to 17 by 22 in. directly on to an 8½ by 13-in. XeroX plate for transfer



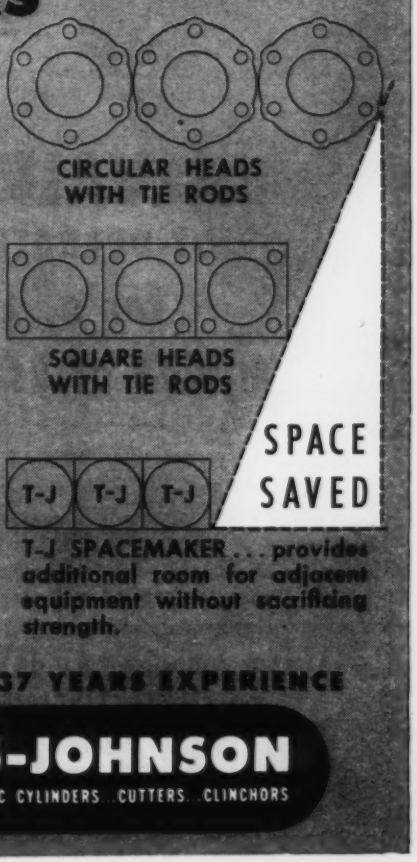

LESS SPACE!

extra high safety factor!

NEW T-J Spacemaker AIR CYLINDERS

These new T-J Cylinders *save up to 40% in mounting space*—with streamlined design that eliminates tie rods. They're *super rugged*—extra high safety factor . . . solid steel heads . . . heavy wall, precision honed, hard chrome plated, seamless steel body . . . leakproof cylinder head to body construction . . . heavy duty, hi-tensile, hard chrome plated piston rod.

Available with the new T-J Super Cushion Flexible Seals which insure positive cushion with automatic valve action for fast return stroke. Many standard sizes and styles . . . for pushing, pulling, lifting, clamping or control jobs. T-J dependability. Write for bulletin 8152. The Tomkins-Johnson Co., Jackson, Mich.



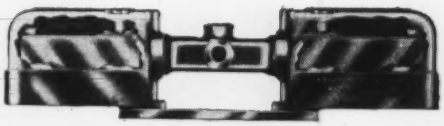

T-J SPACEMAKER . . . provides additional room for adjacent equipment without sacrificing strength.

37 YEARS EXPERIENCE

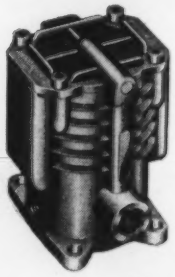
T-J TOMKINS-JOHNSON

RIVITORS . . AIR AND HYDRAULIC CYLINDERS . . CUTTERS . . CLINCHORS

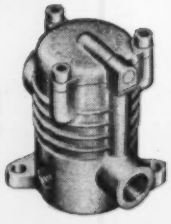
4 Weeks Delivery on the Spacemaker—any style, any stroke, 1" to 3" diam.



FIRST



THEN



NEXT

NOW WHAT?

Diversatility SCORES AGAIN!

A New BUT Thoroughly Proven

VALVAIR SOLENOID PILOT-OPERATED CONTROL VALVE

for a myriad of uses!

Expect and get 20,000,000 cycles and more without maintenance. Most compact — extremely small, weighs very little. Just one moving part — the acme of simplicity and trouble-free performance. Complete line—30 valves in all. Get all the details NOW.

More information next month

ASK ON YOUR LETTERHEAD FOR BULLETIN "D-9"

VALVAIR CORPORATION, 953 Beardsley Ave., Akron 11, Ohio

AFFILIATE: SINCLAIR-COLLINS VALVE CO.

Rely Upon Valvair 2-WAY 3-WAY 4-WAY


## Engineering Equipment

to a paper master by the xerography process. It permits reduction to 50 per cent and enlargement to 150 per cent. A relay on the control box operates the lights only when the shutter is open. Four thermal shock-resistant 300-w lamps provide illumination which reduces the former exposure time by one-half. The camera fits on 5 by 2 ft table; over-all length with copy board down is 73 in.; width including extending lights is 58 in. Made by the **Haloid Co.**, Rochester, N. Y.

For more data circle MD-93, page 209

## Pocket Comparator

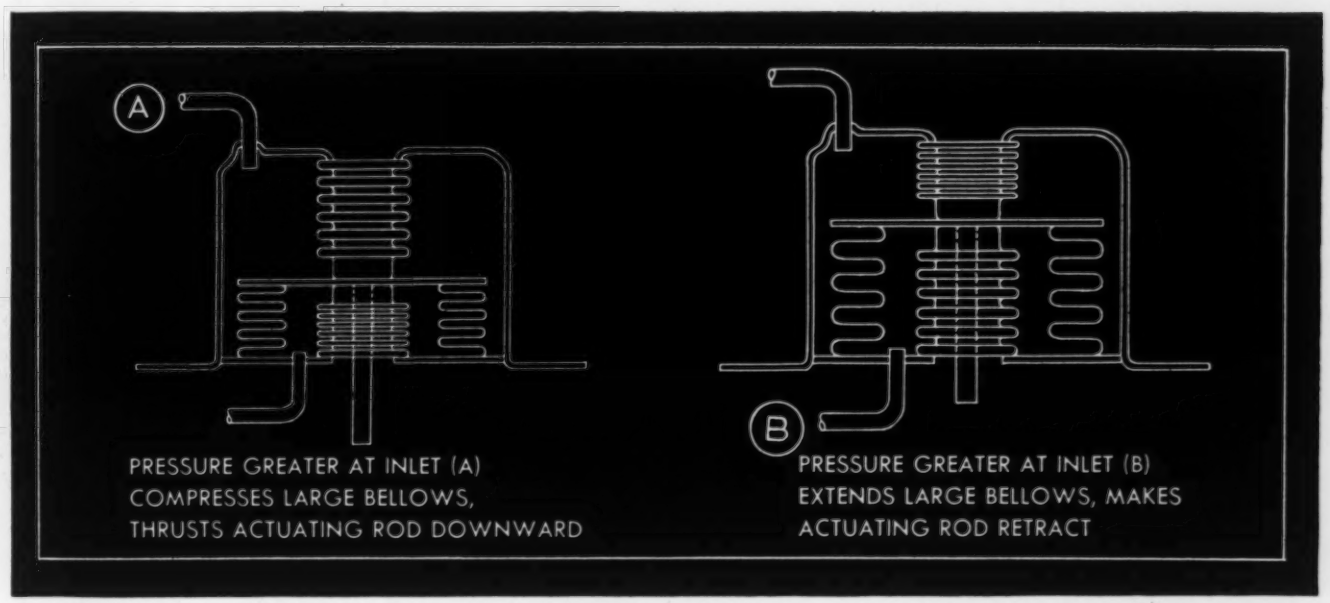
Designed for fast, accurate measurement of small parts and dimensions, this pocket comparator is only 1½ by 2 in. in size. Providing 6-power magnification, the device has a reticle calibrated to measure angles, radii, circles and linear dimensions, in both decimal inches and millimeters. Instrument comes in protective leather case. Available from **Edmund Scientific Corp.**, Dept. 277, Barrington, N. J.

For more data circle MD-94, page 209

## Digital Point Plotter

The high-speed model CCP 701 digital point-by-point plotter is used primarily for preparing curves and graphs of data received from general-purpose digital computers. It has an aluminum plotting drum 12 in. long and 6 in. in

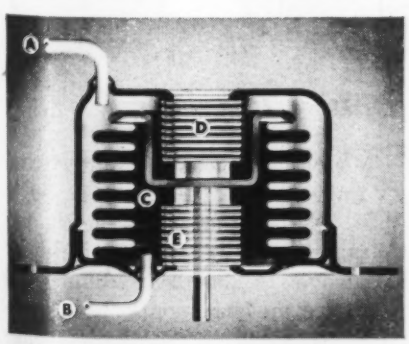
# Differential Pressure Problems Solved by Bellows




**AMONG THE MANY USES** of the new differential pressure Clifford bellows assembly is the maintenance of absolute pressure in aircraft fuel systems. Manufacturers of thermostats or pressure switches which must not be affected by barometric changes due to altitude or other factors also find the new assembly an ideal control unit . . . for vapor pressure thermostats, for instance.

The assembly is useful, too, for flow indication or control. Pressure drop across an orifice or venturi can be used to "sense" flow in a closed system. A sensitive bellows can be used since the large bellows is subjected to differential pressure only.

Generally, the unit can be applied to all types of industrial processes where pressures within a fluid system must be automatically equalized or where absolute rather than gauge pressure must be maintained.




**THIS CLIFFORD DIFFERENTIAL BELLOWS ASSEMBLY CONSISTS** of large operating bellows (C) and two smaller sealing bellows (D), (E). Pressure can be applied at either side of large bellows. The movement of the actuating rod is then proportional to the *difference* between pressures on the inside and outside of the large bellows. Either side of the large bellows can also be evacuated and sealed. In this case, the movement of the rod is a function of *absolute* pressure. The rod is used to operate switches, valves or any similar devices to control an indicated differential or absolute pressure.

The assembly comes in a variety of materials . . . brass, stainless steel, monel or any metal having suitable drawing property for making bellows. It can be adapted to all combinations of sizes and pressures for which bellows are available. For further details, write direct Clifford Manufacturing Company, 124 Grove Street, Waltham 54, Massachusetts. *Division of Standard-Thomson Corporation.* Sales offices in New York; Detroit; Chicago; Los Angeles; Waltham, Massachusetts.

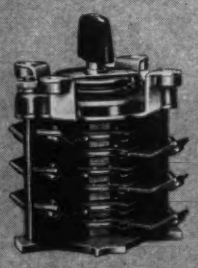
**FLEXIBLE, LEAKPROOF, METALLIC, CLIFFORD BELLOWS are also used to**

1 transmit motion between two mediums
2 control and indicate temperature
3 seal rotary shafts or packless valves
4 transmit motion hydraulically to remote points
5 provide for thermal expansion
6 provide shock mounting or vibration dampening
7 permit motion in a vacuum

# ROTARY SWITCHES

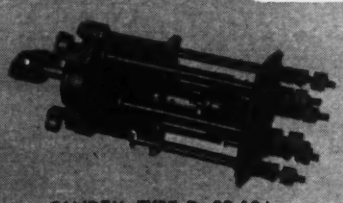
*For every control, tap, and transfer application.*

TYPE JR

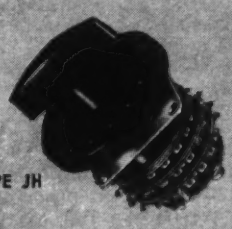


TYPE P, 30A

TYPE A



TANDEM TYPE P, 30-10A



TYPE JH

- Save valuable panel space
- Simplify control of complex circuits
- Give "dead-front" mounting safety
- Listed by Underwriters Labs, Inc.
- Can be furnished to latest Navy specs.
- Ratings from 2 amperes to 200 amperes, 30 to 250 volts d. c., and 125 to 500 volts a. c. — depending on number of circuits and nature of load.

**Write for combined catalog giving useful design data on Esco rotary switches.**

**ELECTRO SWITCH**
CORPORATION
167 King Avenue, Weymouth 88, Mass.


## Engineering Equipment

diameter, capable of producing 11 by 17-in. plots. Plotting speed is 2 seconds per point. Various stylus-symbols are available. An optional decimal keyboard is available for manual plotting, and provision can be made to plot data from magnetic and paper tape or IBM card readers. Made by **California Computer Products,** 3927 West Jefferson Blvd., Los Angeles 16, Calif.

**For more data circle MD-95, page 209**

## Multiple-Purpose Computer

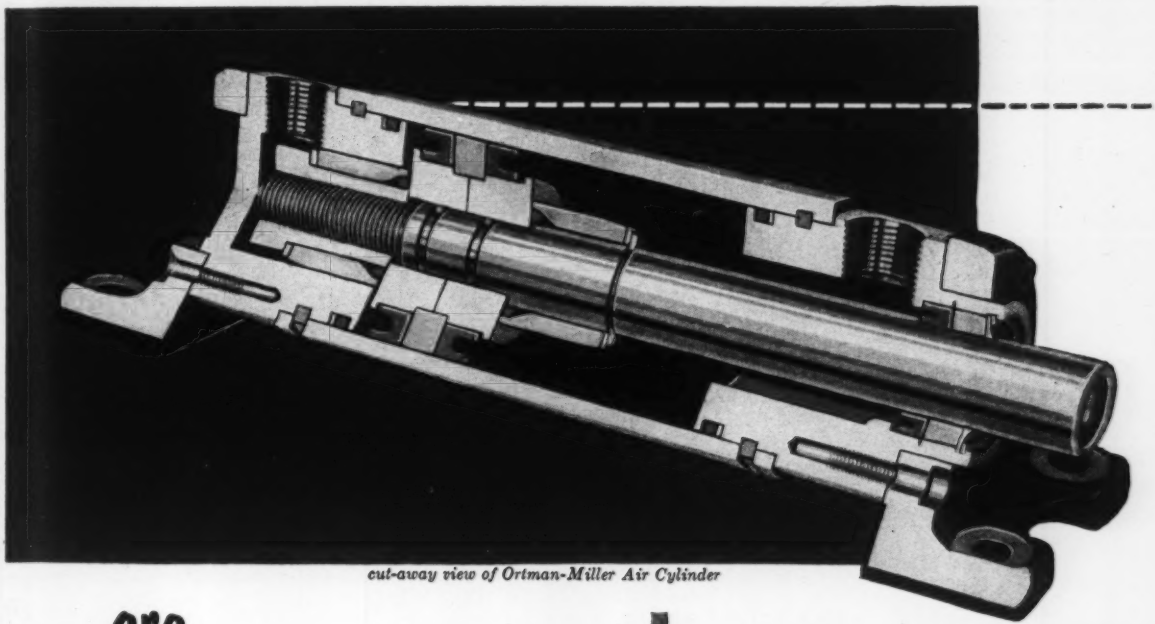
The GraphAnalogue has been developed for data reduction, scaling and design engineering calculations. The unit has an infinitely variable scale. On its upper surface are eighteen scales, including three linear and three reciprocal scales, in inch, foot and centimeter dimensions, along with logarithmic, probability, trigonometric and power scales. By setting the hairline indicator any desired scale can be produced. Graphs or curves can be multiplied directly with this instrument and distances can be divided into any number of equal spaces, into logarithmically proportional lengths, or into any arbitrary nonlinear proportion. The main body of the unit is made of aluminum. Made by **Gerber Scientific Instruments Co.,** 89 Spruce St., Hartford 1, Conn.

**For more data circle MD-96, page 209**

## Pressure Transducer

Model P97 measures differential or gage pressure in the range 0 to 0.05 psi. Its stainless steel diaphragm permits measurement of corrosive fluids. For differential pressure measurements, the transducer is supplied with a reference pressure connection to the case cavity into which noncorrosive gases may be introduced. Output is 3.5 millivolts per volt full scale open circuit. The unit is used in the investigation of both static and dynamic pressures. Specifications include: nominal bridge resistance,

# O-M AIR • HYDRAULIC CYLINDERS



*cut-away view of Ortman-Miller Air Cylinder*

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O-M Cylinders "Fit Where Others Won't." They have the lowest coefficient of friction of any cylinder, thus, are smoother operating at low or high speeds. All end plugs are tapped for universal mounting.

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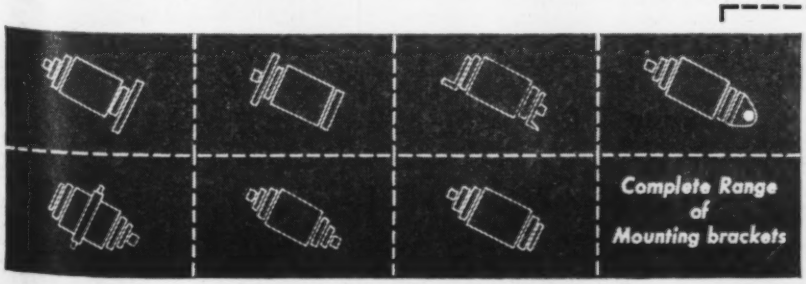


*interchangeable bore for bore*

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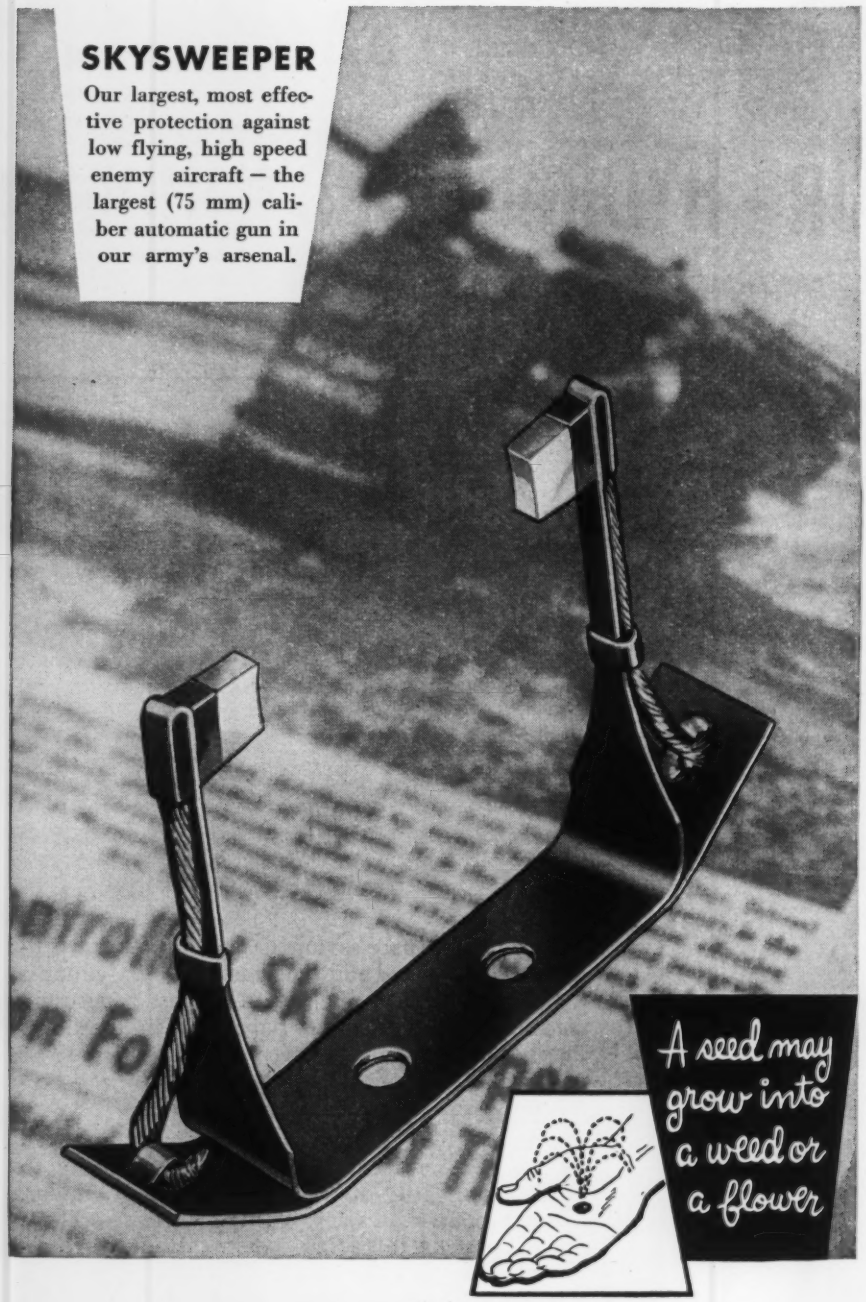
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## Engineering Equipment

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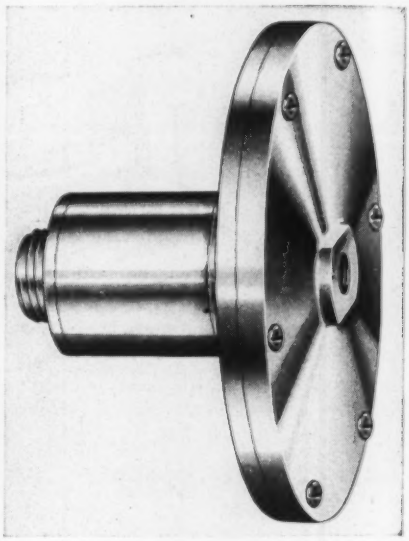
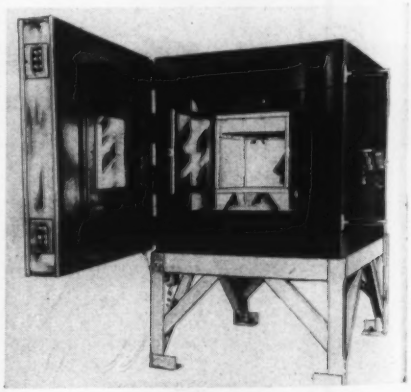


line pressure, 15 psi; temperature limit, −65 to 250 F; resolution, 0.1 per cent or better; weight, 2¼ lb. Made by **Statham Laboratories Inc.**, 12401 West Olympic Blvd., Los Angeles 64, Calif.

For more data circle MD-97, page 209

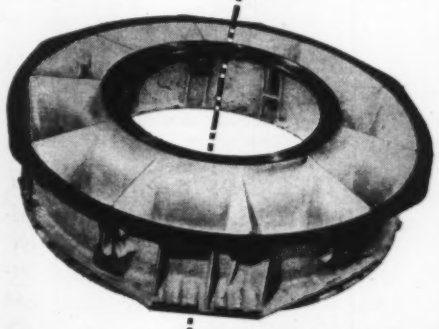
## Nonmagnetic Test Chamber

Used in determining effects of temperature on electrical fields in the development testing of pure



metals, this unit contains no steel. It is constructed of brass, copper, aluminum, rubber, bakelite, glass,

# Ductalloy® castings make "impossible" parts producible



Wright J-65 jet engine main bearing support... impractical to machine from one piece. Readily produced as a weldment of two Ductalloy precision castings.

This highly stressed part secures the 7,200-lb. thrust Wright J-65 jet engine in the aircraft, carries major structural members ahead of and behind it, and mounts a main shaft bearing in its center. Air roars between the carefully contoured inner and outer rings.

As originally hogged out from an aluminum forging on an experimental basis, this part required some 1200 hours of machining—impractical for volume production. Redesigned by Curtiss-Wright Corporation's Wright Aeronautical Division as a weldment of two Ductalloy precision castings, it requires only simple turning and facing plus 25 ft. of welding to assemble the ten interconnecting stainless steel struts. An "impossible" part for volume manufacture in other metals which would meet specifications, it is rendered readily producible in Ductalloy—Brake Shoe's ductile cast iron that combines high strength with the casting and machining qualities of gray iron.

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*Ductalloy castings are made by:* BRAKE SHOE & CASTINGS DIVISION
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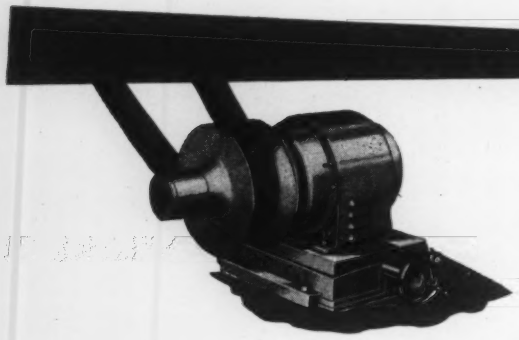

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**If it's speed control—it's a job for**

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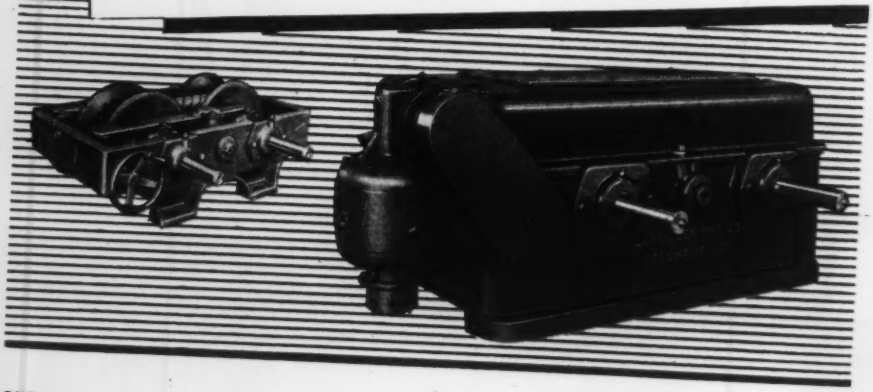
**TRANSMISSIONS—MOTOR PULLEYS**



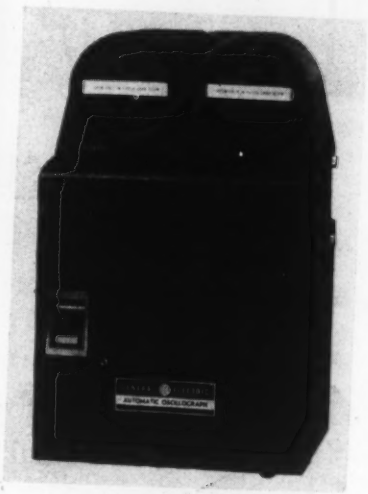
## Engineering Equipment

wood and Fiber-glass. Motors and electrical components are located approximately 6 ft away to eliminate effects of their electrical fields. The unit produces any temperature from −112 F to 68 F, with close temperature control. An inner chamber thermally governed by vernier control holds temperatures to ±0.1 F. Developed by **Bowser Technical Refrigeration,** Terryville, Conn.

For more data circle MD-98, page 209

## Recording Instrument

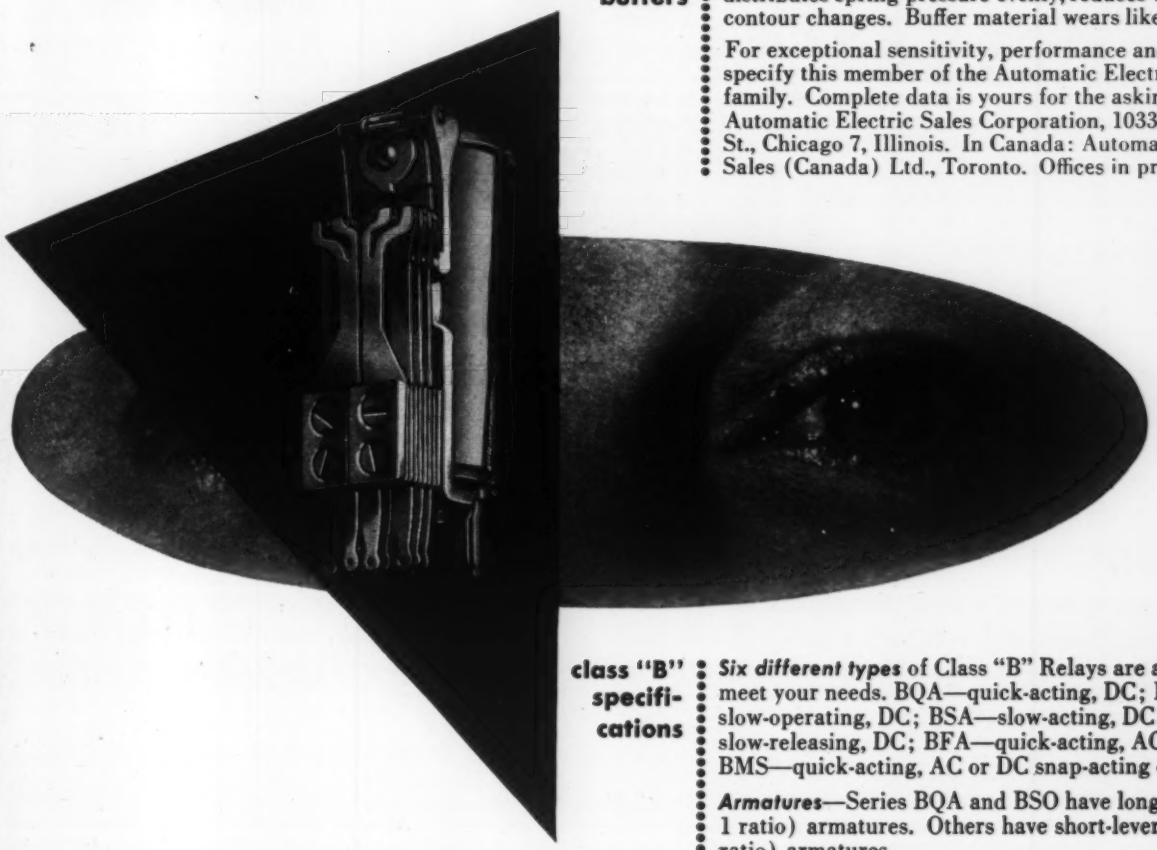
For photographically recording power system disturbances, preselected magnitudes, wave shapes and phase relations, PM-13 oscillograph has seven galvanometers with separate shunt and resistor unit for adapting them to current or voltage measurements. Relays and controls are provided for



starting the instrument automatically by overcurrent in ¼-cycle, and stopping it after a predetermined interval or after fault has been cleared. Units provide information on circuit-breaker, relay and system performance and on fault location. Including a time recorder which photographically establishes date and time of each oscillogram, unit measures 16 in. wide, 23-7/16 high and 10¾ in. deep. Made by **General Electric Co.,** Schenectady 5, N. Y.

For more data circle MD-99, page 209

# Take a Critical Look Inside...



**an Automatic Electric class "B" relay**

**advanced features**

This Class "B" Relay meets stresses at critical areas . . . the stresses and strains of hundreds of millions of operations . . . with advanced features that are standard equipment.

**no backstop to wear**

The conventional backstop has been eliminated. Working tips of the armature arms rest against non-magnetic discs, spot-welded on the heelpiece at points of contact with the armature, to prevent magnetic "freezing". There is one less part subject to breakage, wear and need for readjustment.

**armature "sag off" eliminated**

Armature arms are extra-thick, designed to handle any spring load, even under constant, heavy use. There is no "sagging off" or any other such loss of stroke.

**pin-type armature bearings**

The bearing pin is fixed to the armature, and turns in a yoke with a large bearing surface, packed with solid, long-lasting lubricant. A wear-resisting plate gives the bearing pin a full-length bearing surface. The bearings last and last and *last!* The air-line remains clearly visible, can be checked easily.

**wear-resisting buffers**

Dome-shape buffer design eliminates "wearing-in", distributes spring pressure evenly, reduces wear and contour changes. Buffer material wears like iron!

For exceptional sensitivity, performance and durability, specify this member of the Automatic Electric relay family. Complete data is yours for the asking. Write: Automatic Electric Sales Corporation, 1033 W. Van Buren St., Chicago 7, Illinois. In Canada: Automatic Electric Sales (Canada) Ltd., Toronto. Offices in principal cities.

**class "B" specifications**

***Six different types*** of Class "B" Relays are available to meet your needs. BQA—quick-acting, DC; BSO—slow-operating, DC; BSA—slow-acting, DC; BSR—slow-releasing, DC; BFA—quick-acting, AC; and BMS—quick-acting, AC or DC snap-acting contacts.

***Armatures***—Series BQA and BSO have long-lever (2 to 1 ratio) armatures. Others have short-lever (1 to 1 ratio) armatures.

***Contacts***—Normally twin. Load carrying capacity, 150 watts (maximum 3 amps.).

***Contact spring capacity***—Series BQA, BSO and BFA, 13 springs per pile-up. Series BSR and BSA, 6 or more springs per pile-up. Series BMS, 1 or 2 snap-action switches.

***Dimensions***—Series BQA, BSO, BSA, BSR, and BFA—over-all length, $4\frac{3}{32}$"; width, $1\frac{9}{16}$" to $2\frac{1}{4}$" (depending upon number of springs); height, $1\frac{1}{32}$". Series BMS—over-all length, $4\frac{3}{32}$", width, $1\frac{23}{32}$", height, $2\frac{9}{32}$".

*For more detailed information, ask for Circular 1801.*

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more economically with
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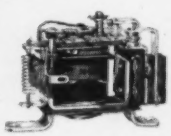
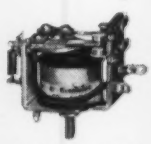
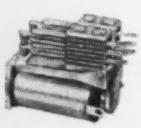
PR Heavy Duty Power

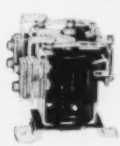
KL Multiple Contact

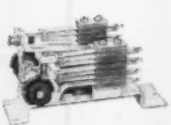

MR Medium Duty Power


KR Light Duty Type

LK Latching Type


MH Miniature Telephone


LM Plate Circuit Type


AP Sequence Impulse Type

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# Stress Relief

SOMETIMES in the history of science or engineering one finds means for the alleviation of today's trials and problems. Well, for a moment at least, we hope the following account offers some stress relief.

Gene Murphy is the reporter of this 400-year old development and the scoop appeared originally in Minneapolis - Honeywell's publication, *Instrumentation*.

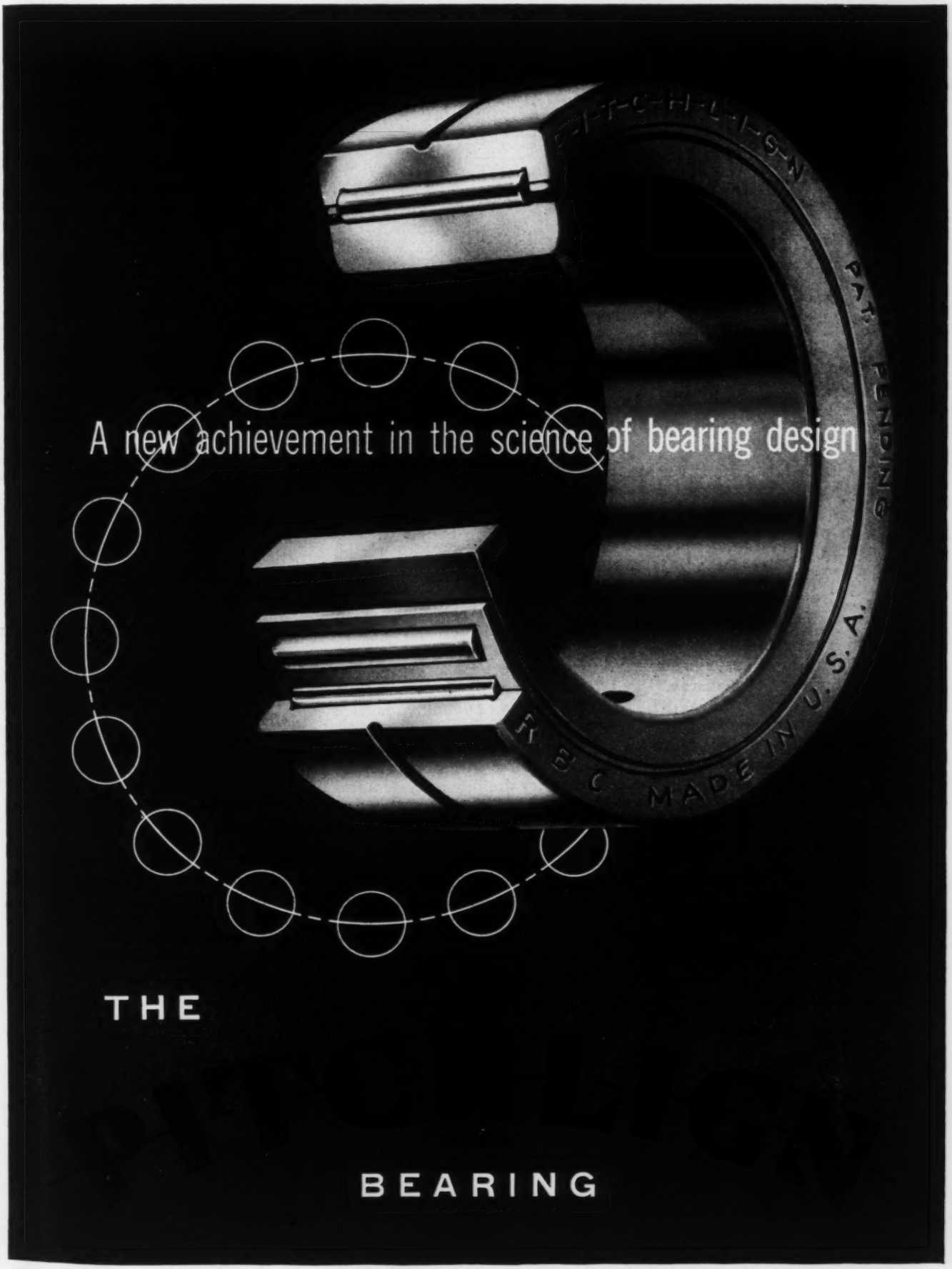
**the attempt and not**
**the deed confounds us***

Toward the middle of the Sixteenth Century, there dwelt in the very shadow of the Tower of London a coarse fellow whose vocation it was to extract, by such means as were then considered appropriate and fitting, confessions of crimes from those unfortunates who had incurred the displeasure of the feudal lords of the day, and who had been entrusted to the offices of the Lord High Executioner. Able and willing as this fellow was at the tasks assigned to him by the Lord High Executioner, he constantly dreamed of turning base metals into gold, for alchemy was his avocation and the one great joy of his life.

Although this uncouth fellow—Launcelot Guinevere[1] Smythe-Smythe by name—possessed neither learning nor the wherewithal to absorb such learning (were the opportunity to present itself), he was filled with the conceit that one day he would accomplish that which others before him had failed to do, and would be duly proclaimed far and wide as the foremost alchemist of the realm.

Toward this end, he had crammed into the dingy garret, wherein he dwelt, a motley assortment of things the likes of which he had heard must needs be the equipment of any learned and self-respecting alchemist. And nightly, having concluded his duties in the

*Shakespeare.
[1]We wondered about this, too.

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## Stress Relief

torture chambers, he would hie himself to this room, there to concoct nauseous brews, and to mix carefully with certain ingredients, other ingredients, the addition of which did bring about strange bubblings and gurglings, and, at times, did result in the garret being filled to the rafters with fumes and vapors of such an obnoxious stench as to well nigh asphyxiate poor Launcelot on more than one occasion.

Now it so befell that on a rainy night in June of the year 1556, the day's arduous tasks in the dungeons having been completed, Launcelot brought back with him to his room one Cholmondley, a young apprentice at the rack and wheel, who, in an effort to insinuate himself into the good graces of his mentor, had expressed a most extraordinary interest in alchemy and things pertaining thereunto.

**Research—Phase One:** Delaying only long enough to consume, each one, in lieu of supper, three or four tankards of ale, the two straightway fell about the task of transmuting into gold a small quantity of lead filched from the melting pot in the torture chamber. Beakers and vessels and pots they placed upon a table. A pinch of powdered unicorn horn, a dash of ground frogs' eyelashes, and a small quantity of ale that was as yet unconsumed did Launcelot add carefully to the vessel containing the lead, while the apprentice did kindle a small blaze beneath a huge flagon which held a mixture of thieves' blood, witches' hair and murderers' eyes (purloined from the torture chamber's spare parts chest), along with carefully calculated amounts of still unidentified chemicals borrowed, without permission, from the queen's physician.[2]

In less time than is taken to describe the happening the flagon did begin to spew out fumes so nauseous and horrible in nature that Launcelot and Cholmondley, even though accustomed to the odor of burning hair and flesh, did straightway lose their three tankards of ale and the better part of

[2] Launcelot's descendants later sold the recipe to a patent medicine manufacturer.

yesterday's noon meal before the apprentice, being a lad of small learning but nimble brain, bethought himself to clap over the mouth of the flagon a pig's bladder, which he then made secure around the flagon's neck with the lace from his points.[3]

Having thus effectively put a stop to the emission of the foul fumes, the two did hastily betake themselves to the tavern to apply to their writhing stomachs a dosage of mayhap three or four tankards of ale.

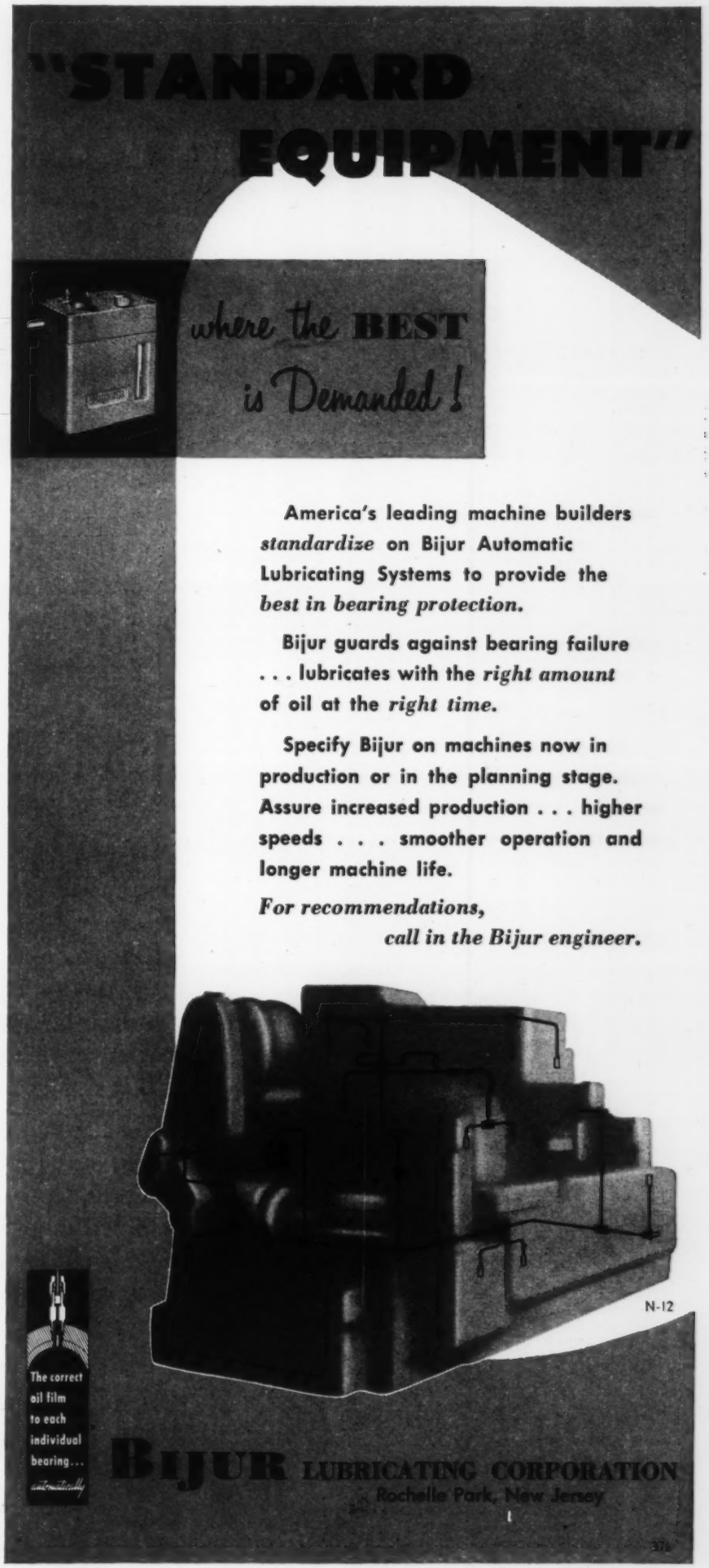
**Research—Phase Two:** Now, also in the tavern, and covertly listening to their talk, was a great man from the Queen's Court, a learned man, one Fotherington Wormwoode, who was much given to watching and listening to other people, and to purloining for himself whatever of interest such people did devise. Forsooth, it was in this manner alone that Wormwoode had come to be a great and renowned scientist, for he was of the few who could read and write and cypher, and although others might devise things and talk about them, they were in no wise able to lay claim to these ideas when this great man did show unto the queen a wondrous parchment on which was set forth the manner in which these devices did operate, and even drawings showing their very construction.

And so this Wormwoode did follow Launcelot and Cholmondley back to their room and did peer through a crack in the door and observe that which took place. And that which he saw at first affrighted him, for the pig's bladder had swelled to the size of a small wine cask and was even yet growing larger.[4]

Cholmondley, being somewhat more nimble in the brain than was Launcelot, and perceiving at a glance that lest something were done, there would occur a great letting forth of repulsive fumes, took hold of the bladder with both hands and did attempt to squeeze back into the trembling flagon the fumes which were soon like to rend the

[3]They had something to do with holding up one's hose.

[4]In the average pig, this condition would have been regarded as fatal.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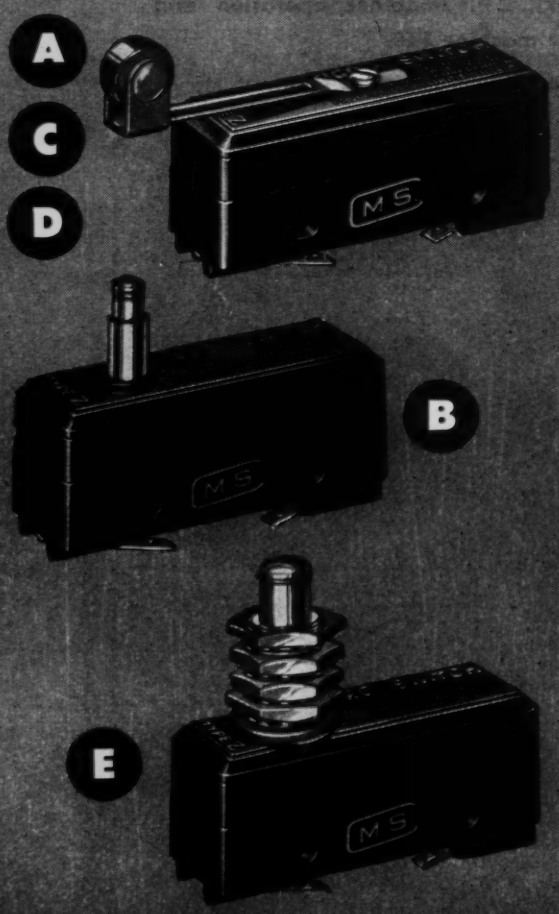
# 24 MICRO precision switches perform vital functions

## These 3 MICRO switches of 8 different types function to make Robot the first fully automatic washer

**● The three designs of MICRO switches shown include eight different types of operating characteristics and circuit arrangements required as controls for the Robot washer.**

**All have the MICRO characteristics of small size, light weight, accurate repeatability of operating point, high electrical rating and long-life dependability.**

**Letters indicate the location of these three MICRO switch designs in the open view of the Robot washer on the opposite page.**




● This fully automatic commercial washer, which does the work of two or more manual washers, was developed by engineers of the Robot Laundry Machinery Sales, a division of the Wolf Company, Chambersburg, Pa.

Through the use of 24 MICRO precision switches, of eight different types, the designers were able to produce the first and only self-contained and completely automatic washer.

Under the automatic control of these MICRO switches, the Robot Washer—

1. Pre-mixes and releases supplies
2. Measures pre-determined gallonage of water
3. Controls water temperatures
4. Times each washing cycle
5. Injects steam at proper time
6. Dumps washer when cycle is completed

MICRO switches were chosen by Robot design engineers because of their long-life dependability and high electrical capacity . . . plus the ability of MICRO engineering to provide all the different types of switches which were required to control each operation most efficiently.

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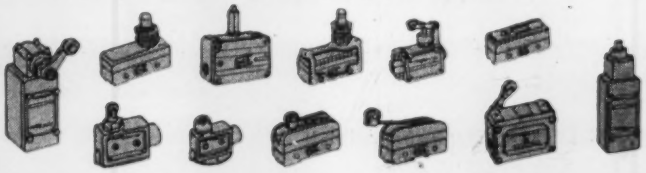
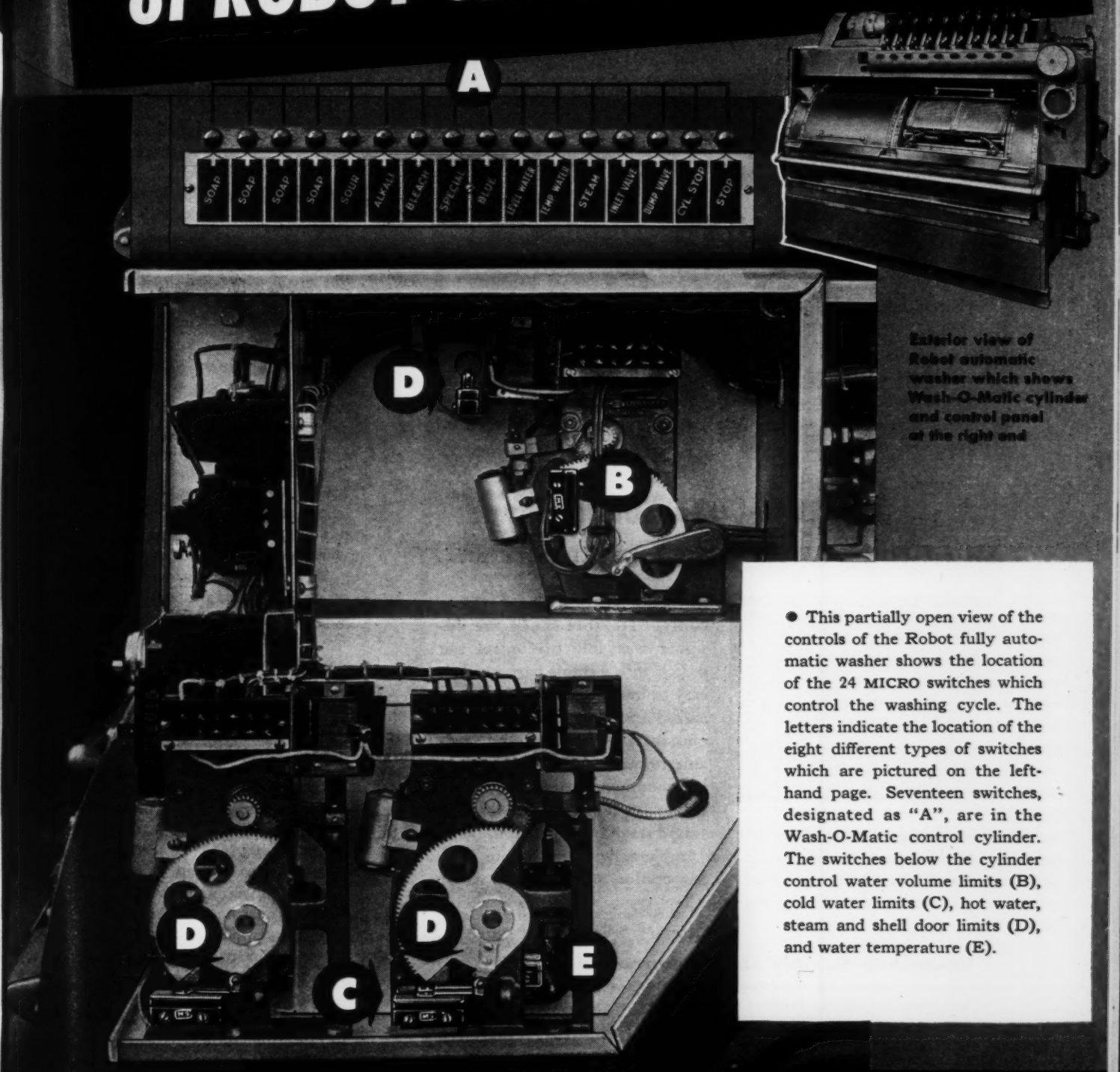


# to provide automatic control of ROBOT commercial washer




Exterior view of Robot automatic washer which shows Wash-O-Matic cylinder and control panel at the right end

● This partially open view of the controls of the Robot fully automatic washer shows the location of the 24 MICRO switches which control the washing cycle. The letters indicate the location of the eight different types of switches which are pictured on the left-hand page. Seventeen switches, designated as "A", are in the Wash-O-Matic control cylinder. The switches below the cylinder control water volume limits (B), cold water limits (C), hot water, steam and shell door limits (D), and water temperature (E).

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## THE PROBLEM

### TO CONTROL AN INACCESSIBLE PART

The designer of the unit pictured below was faced with the problem of providing an economical method of operating an inaccessible rotary switch from a convenient point outside the unit. The control linkage had to have a minimum degree of "backlash" and had to be run around a 90° turn. The designer considered the many ways in which the control set-up could be done and finally decided on

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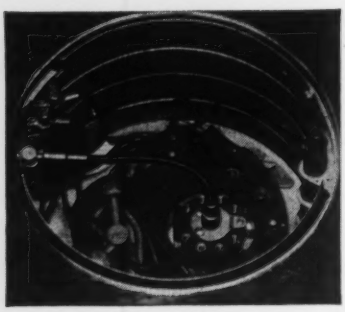

By using an S.S.White remote control flexible shaft, the designer was able to control the switch with a **single** part which is easy to install, requires no alignment, and needs no attention once installed. As a result, he was able to make substantial savings in manufacturing and assembly costs with full assurance that the flexible shaft would fully meet his rigid service specifications. Why not discuss your remote control problems with S.S.White engineers. Their helpful advice and cooperation will show you where you can make similar savings.

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bladder asunder.

"Press ye! Press ye!" screamed Cholmondley to Launcelot. "Press ye with all ye strength, else ye bladder will burst, and we again will loseth our ale!"

While trying in all ways to restrain the swelling of the bladder, the two did jostle the flagon so that it came not into contact with the fire, and behold, as the heat left the flagon, the bladder ceased to swell and did even shrink a bit.

**A Conclusion is Drawn:** And through the crack, the unscrupulous Wormwoode did watch this thing take place, the while wondering at what was happening as the bladder did grow smaller and smaller until at last it had regained its original aspect and proportions. Like those within the room, he marveled when, after the flagon was again placed above the fire, the bladder once more did begin to swell and extend itself. But the two within the room were so astounded by that which did again occur that they forgot, or perhaps did not know, that this which they were doing was a dangerous thing.

The bladder, it appears, was one of an exceptional strength, but not so the flagon, for suddenly, and with a shattering roar that was, it has been said, heard by two old men in a tavern in Exeter, the great flagon burst, enveloping even the scientist outside the door in the clouds of sickening vapors that poured forth, and splattering him with bits and pieces of glass and bladder, and slivers from the door, as well as chunks of Launcelot and Cholmondley.

And when he had recovered himself to consciousness, the scientist bethought himself that he indeed had here the seed of an idea for another wondrous device that he could mayhap invent.

Harkening back, however, to that which had befallen the torturer and his assistant, the scientist, being of the type that loved life with all its pleasures, cast about for some means of doing away with the need for the flagon and the fire, for, being a man of great learning, he was aware that the explosion had been caused by the evil demons within the flagon who had

been angered by their nearness to the fire.

**A Prototype Model is Born:** And so he did devise a system of two bladders, one being larger than the other, and the two being filled with water and connected by a length of pig's intestine.[5] As he pressed upon the larger bladder, he did observe that the smaller one increased in size, and he knew that in truth he had made a great and profound discovery. What it was that he had discovered, or in what manner this discovery might be gainfully employed, he knew not.[6]

He was, however, full well aware of the fact that he did enjoy the favor of the queen only because of those things which he had invented, and that if he invented not at least one wondrous device a month, he was well likely to forfeit his head. Such being the case, he set down on his manuscript that he had perfected "a devysse by which ye can gauge ye amount by which ye presse upon ye bladder of ye pigge." Seeking about for some title, he set down the words "Ye Press Ye Gauge."

This invention—coming as it did on the day on which the fiendish pains of gout did perchance happen to subside in the queen's foot—was the occasion for much feasting and merrymaking, and the queen did cause Wormwoode to be knighted and honored greatly in court. And the parchment whereon was writ a description of the device was handed down from generation to generation in the scientist's family, and each generation did toy with the device and alter in some way its manner of operation until at last it no longer made use of a pig's bladder, but contained instead what was called a Bourdon tube. At the same time, as the English language itself did change, the name of the device grew to be "pressure gage" and it came to be used by many people who sought to know what manner of things were going on inside of a vessel, so that they might, perhaps, do something about these things or else remove themselves from the location ere the vessel did burst.[7]

[5]Ye English pigge gave his all for science.
[6]Many research men have this trouble.
[7]The same feeling still prevails.


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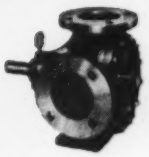

MODELS 7CK-8CK

100 and 200 g.p.m. pumps with flanged ports at right angles. Pressures to 200 p.s.i.

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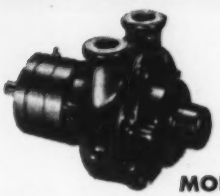

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# Designing Hydraulic Components

## . . . for maximum reliability

DESIGN ABSTRACTS

J. W. Kelly
*Engineering Manager*
*Adel Div., General Metals Corp.*
*Burbank, Calif.*

IN DESIGN, simplicity and straightforwardness are the objectives usually sought and complexity is undesirable. While this is normally true, other factors often enter into the picture which bring up considerations that far outweigh complexity in terms of number of components or number of moving elements. In hydraulic component design, for example, complexity must be considered in terms of the operating forces involved as well as the number of elements making up a particular unit.

Fig. 1 — Failure of original O-ring design, *a*, to meet operating conditions in a steel valve sleeve was corrected in redesign, *b*, which permits loads to be transferred directly to the valve body

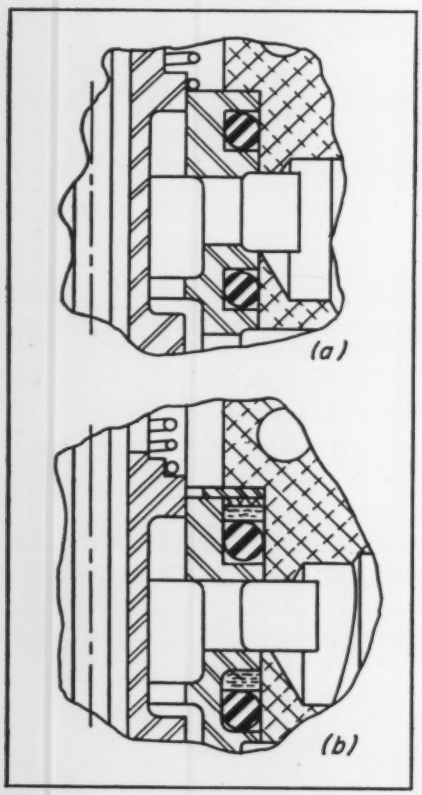
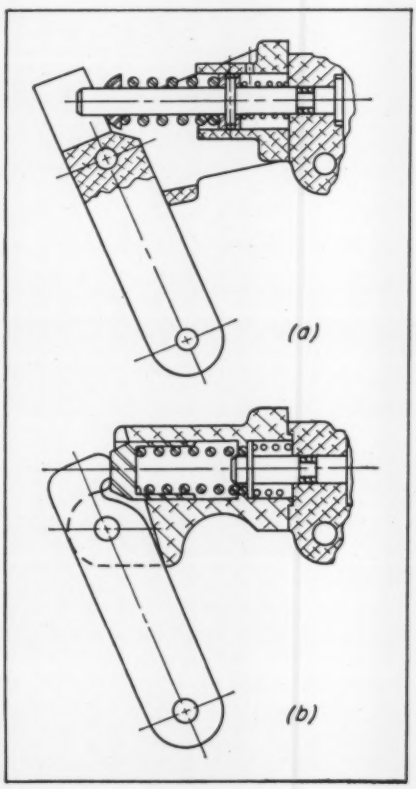



Fig. 2—Manual override, *a*, had a tendency to bind and was redesigned, *b*, to incorporate a cylindrical spring guide




Hydraulic component reliability is often dependent upon the seals employed and many factors must be considered in their selection. For example, frictional forces at −65 F greatly exceed those produced at room temperature. Low temperature combined with pressure and time can cause an otherwise satisfactorily operating valve to malfunction. The quantity of moving O-rings that may be under pressure at temperatures as low as −65 F is considered a far more important factor than the number of elements making up the unit. In addition, the margin of safety between operating forces and friction is definitely more significant than the number of moving parts.

Manufacturing tolerances are a necessity for interchangeable production, but they are often difficult to maintain. In qualification testing, military specifications attempt to take the effect of tolerances into consideration by requiring the manufacture of test units to extreme fits between moving elements. However, this is only part of the picture. There are other tools the designer must use to evaluate the effect of tolerance buildup. A good practice to follow is the utilization of a tolerance chart. Through the preparation and study of such a chart, a design can be better evaluated from the reliability viewpoint. Such a procedure would help avoid unfavorable happenings such as O-rings becoming

wedged in undercut bores as a result of adverse tolerance conditions.

**General Considerations:** The safety factor of a hydraulic component is normally established through the burst test condition, and the designer relies on this to prove his design. However, there are other factors that also need to be adequately evaluated. Since weight is an important aspect of the problem, the maximum allowable stress on springs used in hydraulic components becomes important. Springs in many of these units assume substantial proportions of the weight where it is necessary that frictional forces be kept a small percentage of the overall operational forces.

To keep the weight to a minimum, the designer must use good judgment in selecting maximum allowable spring stress. This factor is considered of enough importance that a movement has been on foot to make spring stress a part of the information on installation drawings for relief valves. Thus, the spring stress is called to the attention of the manufacturer installing the unit. This does not relieve the designer of his responsibility in producing a reliable unit at the minimum possible weight.

Stress concentrations often slip by the most diligent of designers. A typical example occurred with a small, pilot, three-way valve with a spring-loaded poppet. Through an error the poppet nose drawing permitted a sharp corner to be located immediately under the head. This caused a stress concentration on the hardened-steel part, which was discovered only after units were returned from the field. The answer was very simple and involved the incorporation of a generous radius. To avoid such situations the designer must thoroughly analyze any hardened-steel part for stress concentration or inadequate dimensional control that can cause the same result in production manufacturing.

**Dynamic Loads:** Ability of a unit to withstand loads brought about by the operating conditions cannot be neglected. Shaft stops and flanges on O-ring grooves must also be designed for impact loads, and not just for their ability to pass the burst test conditions. The two illustrations in Fig. 1 show the original design of an O-ring groove in a valve steel sleeve and the redesign after failure occurred in the field. The original design adequately passed all of the required test conditions, but still there was failure in the field caused by repeated stress reversals. Redesign was simple and consisted of removing the load from the flange of the O-ring groove and having it transferred to the valve body.

Another example that shows how a unit can be made more reliable by redesign is the manual override shown in Fig. 2. The stage before the redesign had a simple curved cam working between the spring and the lever. During the course of testing, the original prototype of this cam showed a tendency to rotate and make contact with the side walls of the mounting bracket. This tendency was entirely removed in the redesign by adding a cylindrical spring guide which provided the contact between the spring and the lever. This change not only removed the tendency to bind, but also improved the protection to the spring and its associated mechanism, thereby preventing damage from outside contamination.

Another illustration of a "before" and "after" design is shown in Fig. 3. The original design of this coupling and mechanical seal on an electric-driven hydraulic pump satisfactorily passed all performance and endurance tests. However, in the field O-ring seals began to show up with square sections, and there was evidence of rotation on the inside diameter. It became apparent that the friction between the shaft, the O-ring, and the mechanical seal ID was becoming less than the friction between the rotating seal and its associated seal plate. Therefore, it was necessary to provide a mechanical drive connection between the shaft and the seal and the seal was

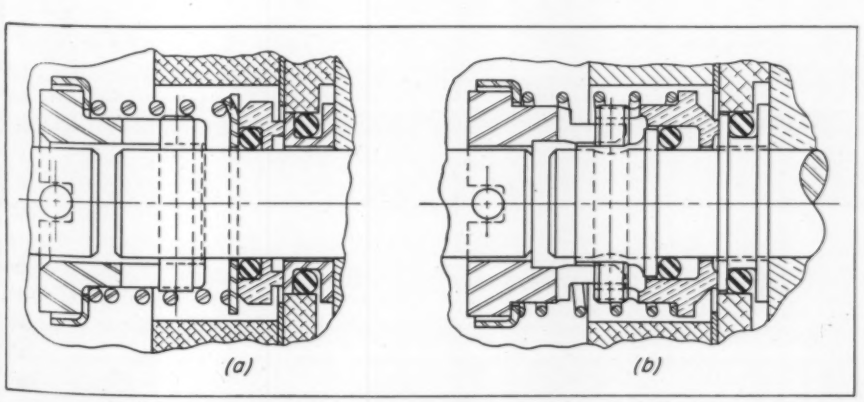



Fig. 3—Above—Unsatisfactory performance of coupling and mechanical seal, *a*, resulted in the redesign at *b* to provide a mechanical drive connection between shaft and seal

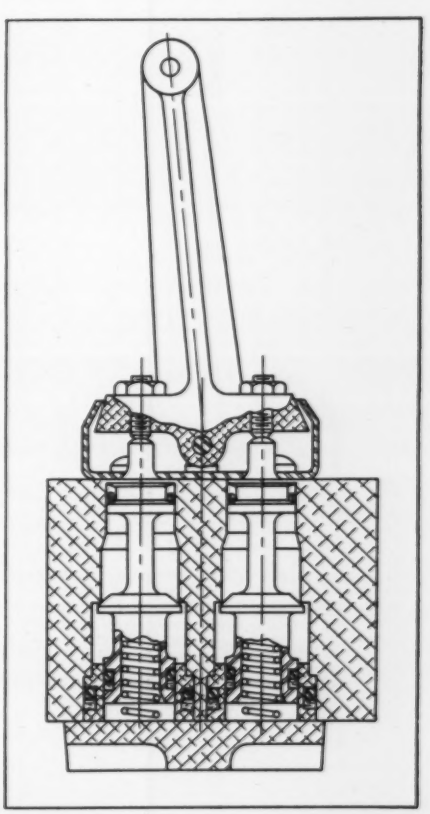


Fig. 4—Right—Valve with walking beam lever arrangement for follow-up system to control a wing flap is design for 20,000 cycle operation

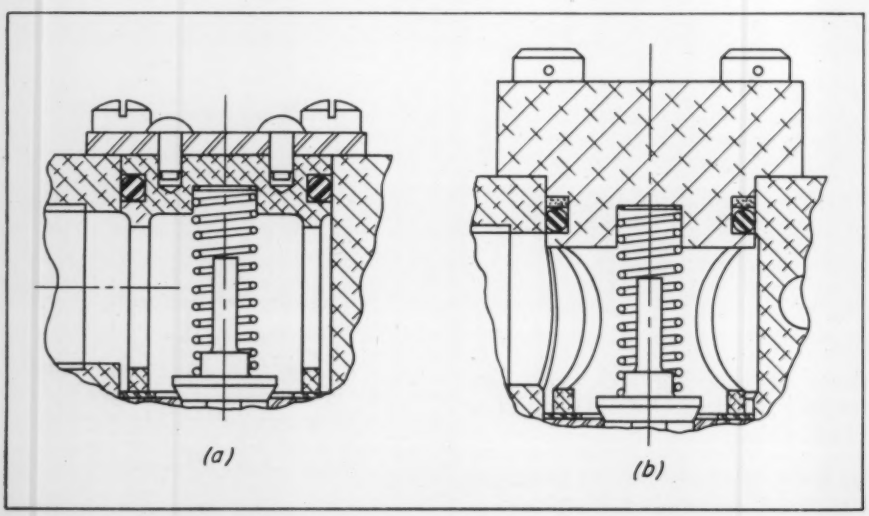
pressure loaded so that inlet pressure conditions not originally specified but obtained in the field received adequate protection. One of the limiting factors on this redesign, which is usually the case with service repairs, is that the minimum of change can be made. Parts must be interchangeable, and there are no increased space allowances in which to provide a better design. Were these factors, pressure loading and positive driving of the mechanical seal, considered in the original design, there could have been adequate space taken to provide even a better and less expensive design.

**Development and Testing:** Laboratory testing of hydraulic components is undertaken first of all to prove that the unit is satisfactory and will perform in the intended manner. In addition, qualification testing is done to prove that the unit will meet specification requirements. Seldom are these two test programs combined. Qualification tests invariably require a long, extensive test program. The actual operating conditions should receive a close review, and wherever possible the unit should be tested in setups approaching these conditions.

**Endurance Characteristics:** Perhaps the most important test is concerned with the endurance of the unit. There should be much attention given to approaching the actual installation requirements. A 20,000-cycle endurance test on a unit which receives 600 cycles per flight is of little value. Thus the number of cycles required should be considered, not from the viewpoint of a standardized specification rate, but from actual aircraft requirements. The test setup for the endurance test should also be similar to its installation. The valve shown in Fig. 4, with its walking beam lever arrangement, is used in a followup system to control a wing flap. This valve passed, with flying colors, an endurance test wherein it was operated manually full open in each direction 20,000 cycles. However, if it had been tested 20,000 cycles in a complete circuit, including a cylinder with followup linkage, the results would have more closely approached the actual field conditions wherein wear occurred on the seat due to the throttling action of the valve. Under actual conditions the valve barely opens.

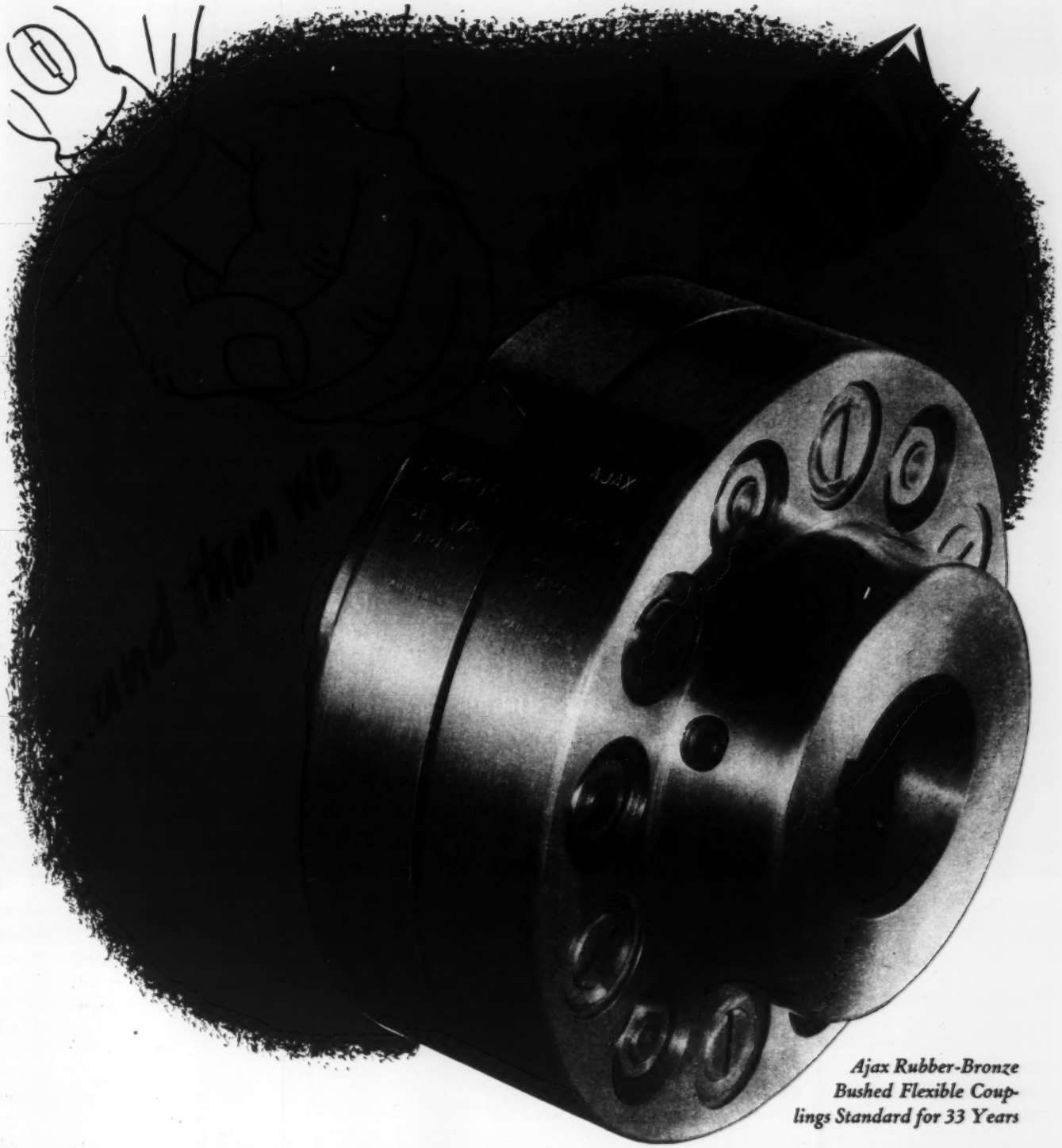
Another factor important to the endurance of the unit is the effect of impulse pressures. It has been found that impulse pressures are more severe as far as structural strength of hydraulic units is concerned than the burst test conditions. Fig. 5 shows the cap construction on a poppet type valve that was designed more than adequately for burst-pressure requirements. The "after" portion of this illustration shows how the cap had to be redesigned to pass the surge test conditions imposed. Surge tests should be conducted on units that are going to be subjected to surge-pressure conditions; however, this test should be applied with caution and not overdone.

Fig. 5—Poppet valve cap construction *a*, had to be redesigned as at *b* to meet heavy surge pressure conditions




**Extreme-Temperature Operation:** High and low temperature tests are routine for hydraulic components, and there again the actual installation conditions are not duplicated. If a valve is to set under pressure at −65 F and then is to be operated, its low temperature test should be conducted with pressure applied to the valve, and not the low pressure applied per current requirements. Obviously, the objectives of the tests must be clear before the requirements are set forth. If concerned only with leakage at low temperature, then perhaps the best test pressure is around 5 psi. If concerned with potential binding, then the best test is with the pressure that produces the greatest frictional forces. A detailed analysis is required of the actual low temperature conditions in order to even set forth a test requirement that is adequate. There is a growing tendency toward specifying dynamic requirements at −65 F and requiring tests to prove these requirements.

In high temperature tests the basic purpose is to test for any tendency to bind as a result of differential expansion of materials. It is also the intention to explore the possibility of packing blowout due to increased clearances. In the case of electric-actuated hydraulic units wherein the performance of the electric unit will vary greatly as the temperature is increased, the high temperature condition should be very clearly defined, and the utmost consideration given to the worst operating condition. For example, on a solenoid valve the worst condition is a test with minimum voltage input for a solenoid that must overcome the maximum load, and with the test conducted after operating at maximum voltage for a period of time sufficient to cause a maximum rise in solenoid temperature. To meet this condition, a solenoid would have to be much heavier than most installations re-

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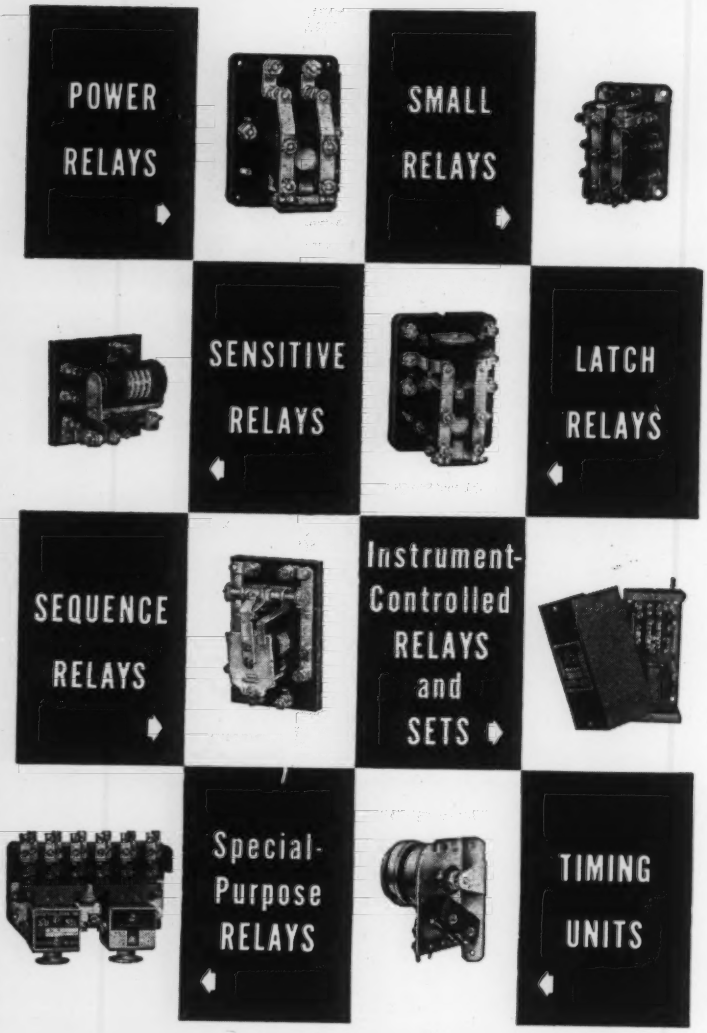


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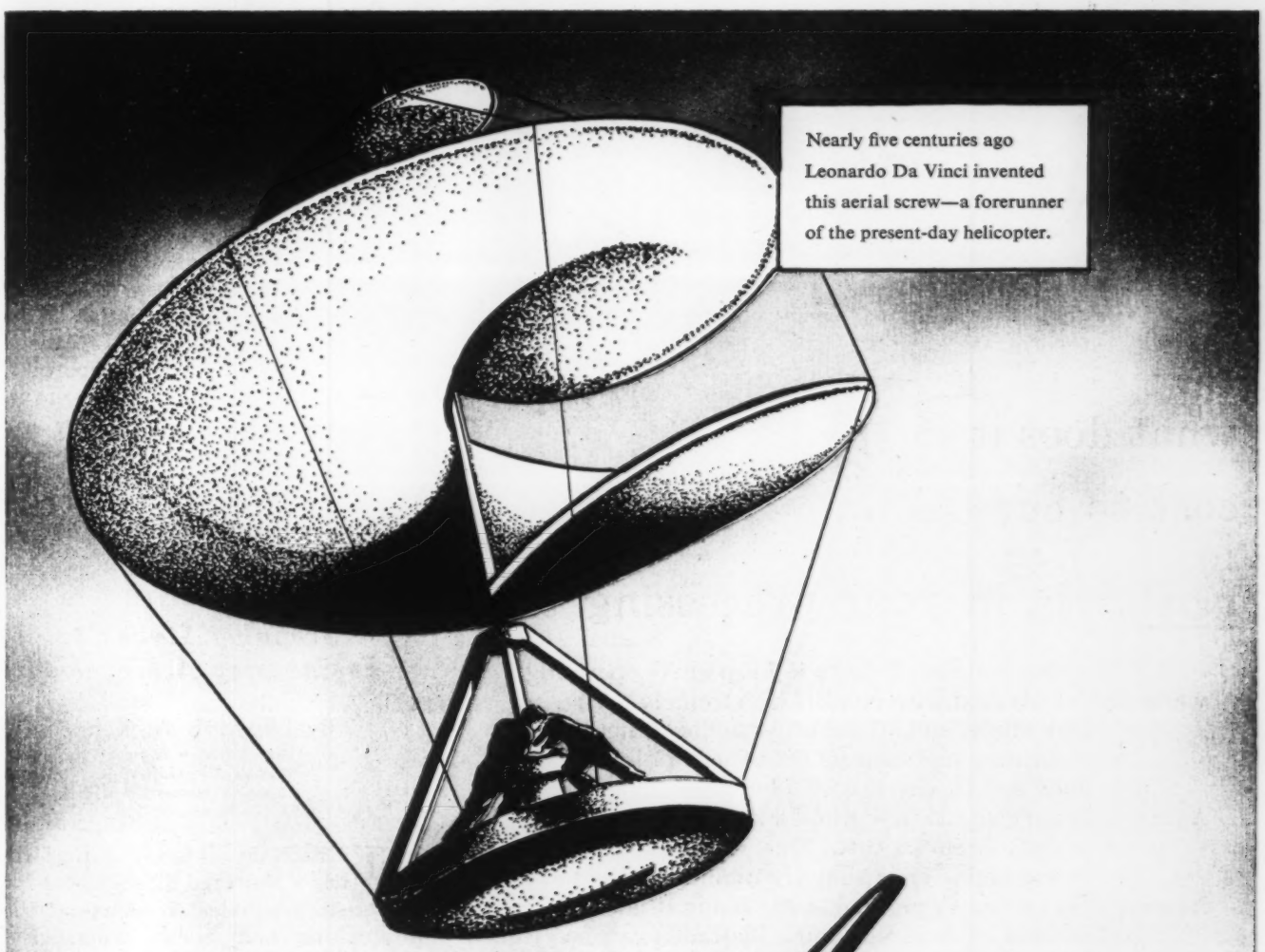
quire; nevertheless, if high temperatures are to be encountered, a test incorporating the appropriate voltage and load conditions commensurate with the high temperature should be specified.

**Performance Requirements:** Normally, routine tests are set forth to measure the performance range of the unit involved. For valves these tests would include items such as pressure drop, operating pressure, voltage, handle load, leakage, and other miscellaneous tests, which are all set forth to evaluate or measure the capacity and functioning of the unit. This type of testing should also include extreme conditions. For example, the pressure-drop test should include flows far beyond the rated capacity of the unit. If this is done as a routine practice, some assurance is provided against misapplication of the unit. A good example of the result of an overflow condition occurred with a poppet valve. The poppet and spring were assembled and the valve was tested under normal conditions; no failure was reported. However, unrestricted pump flow of at least double the rated capacity produced the condition wherein the initial coils of the spring swelled up and went over the head of the poppet. Laboratory evaluation of this showed that six of eleven valves could fail this way when the inlet pressure was increased to 4000 psi and a flow of double the rated capacity passed through the valve. It was further determined that introduction of air into the jumper line connecting the cylinder ports immediately before the test could produce the same failure in all cases. It is not advocated that all units be tested for more than double their rated flow; however, if the unit is going to be subjected to extremely high flows or have accumulators dumping their entire volume through a hydraulic unit, then the unit should be tested under these conditions.

**Production:** Two distinct phases are usually involved in manufacturing a product. The first is the fabrication of the component parts, and the second is the assembly and



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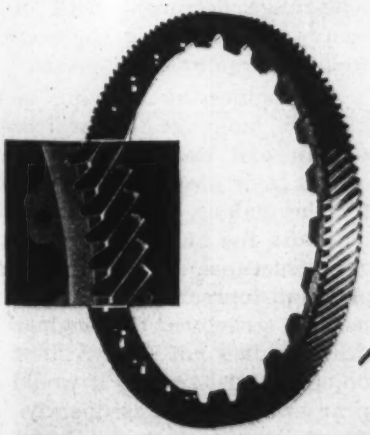

Indiana Gear fabricated this large steel ring gear for the main transmission of a recent model Sikorsky Helicopter without grinding and without heat treat distortion. Originally, the helical teeth on this gear were ground, but a necessary power increase overloaded the part and it failed.

It was assumed to be impossible to successfully heat treat the unground teeth, but I.G.W. produced the part without distortion and the gear operated successfully.

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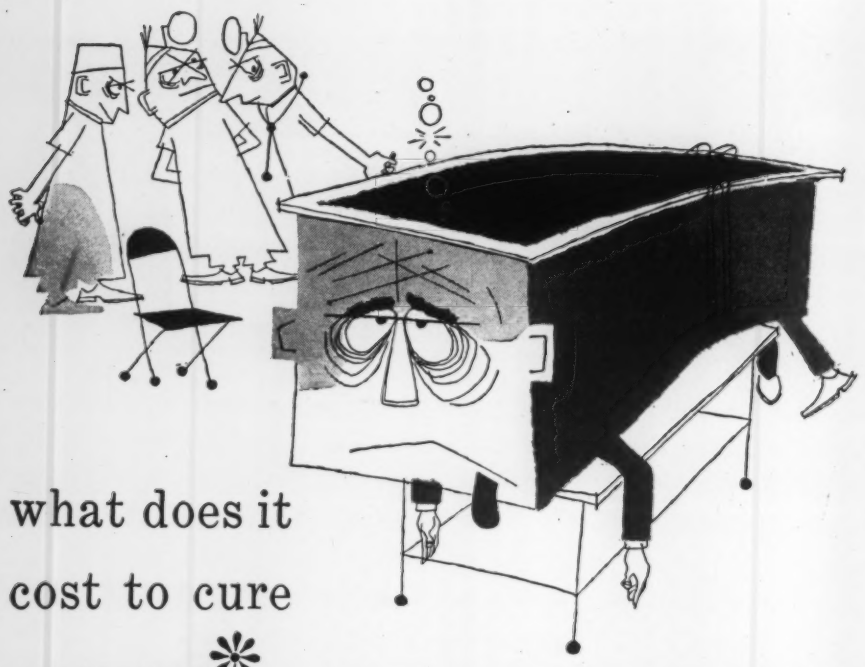

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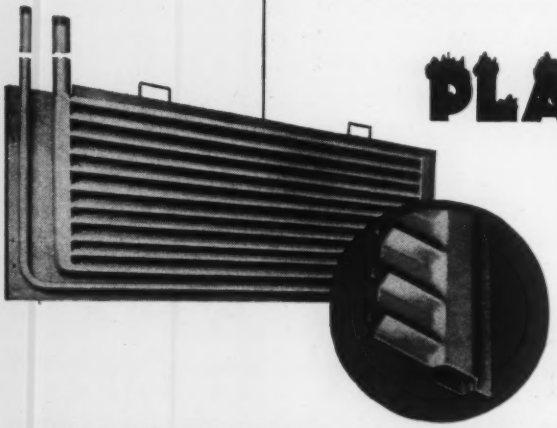

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## Design Abstracts

test of the completed unit. During the fabrication of the components close co-operation between the design engineer and production should exist. An understanding of the functioning of the unit is needed in order to produce parts that will make reliable units. Rigid inspection of raw stock and fabricated parts is essential. Adequate test facilities and realistic test procedures are important.

*From a paper entitled "Design and Development of Aircraft Hydraulic Components for Increased Reliability" presented at the National Aeronautic Meeting of the SAE in New York, N. Y., April, 1953.*

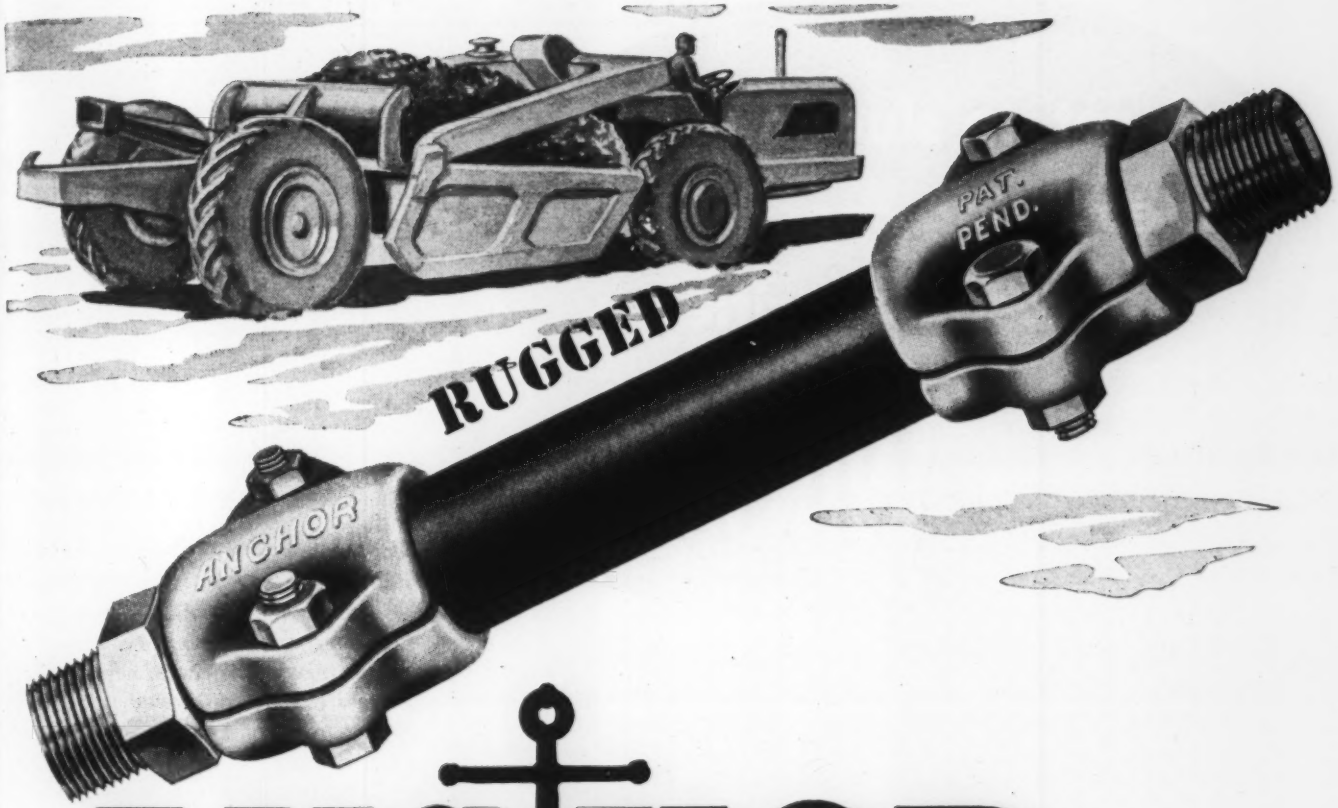
## Stepping Stones to Engineering Achievement

By Ellsworth A. Kehoe
*Administrative Engineer*
*Rochester Products Div.*
*General Motors Corp.*
*Rochester, N. Y.*

THERE is a trend during today's shortage of engineers for recent graduates to short-cut the drafting and design room. Expedient as this now may seem to industry, and opportunistic as it may look to the young engineer, by-passing this important career-development phase may be to the long-range detriment both of industry and of young engineers as well.

An engineering drawing is the graphic language by which designers and engineers convey to others their ideas and instructions for the making of tools and products and the building of machines and structures. Unlike an artist's pictorial representation of an object or structure, the engineering drawing does not always show the object or structure as it would appear to the eye; consequently, this drawing can only be read and understood by those trained in this graphical language.

Because it is the basic method upon which all designing and subsequent manufacture is based, every engineer must know how to make and read engineering drawings. It certainly is not a lan-

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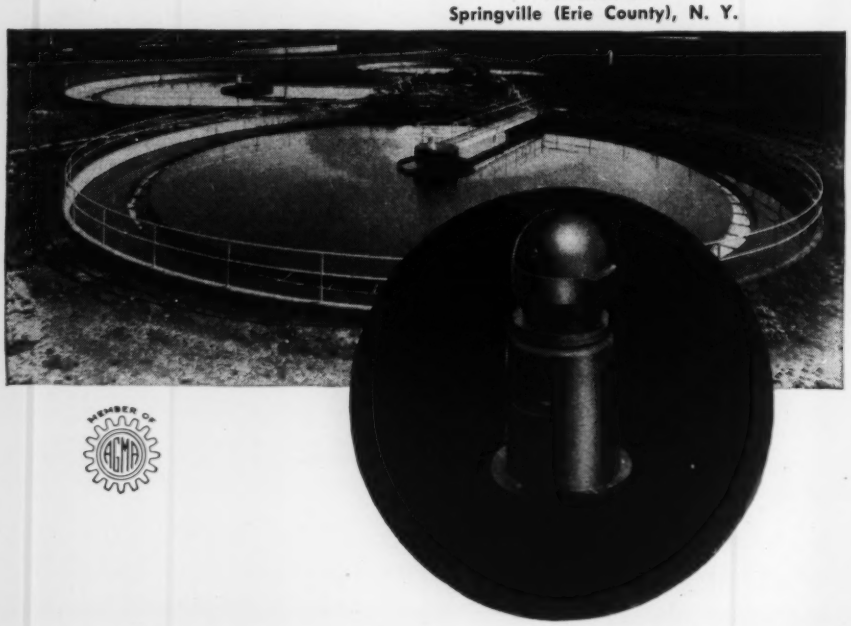


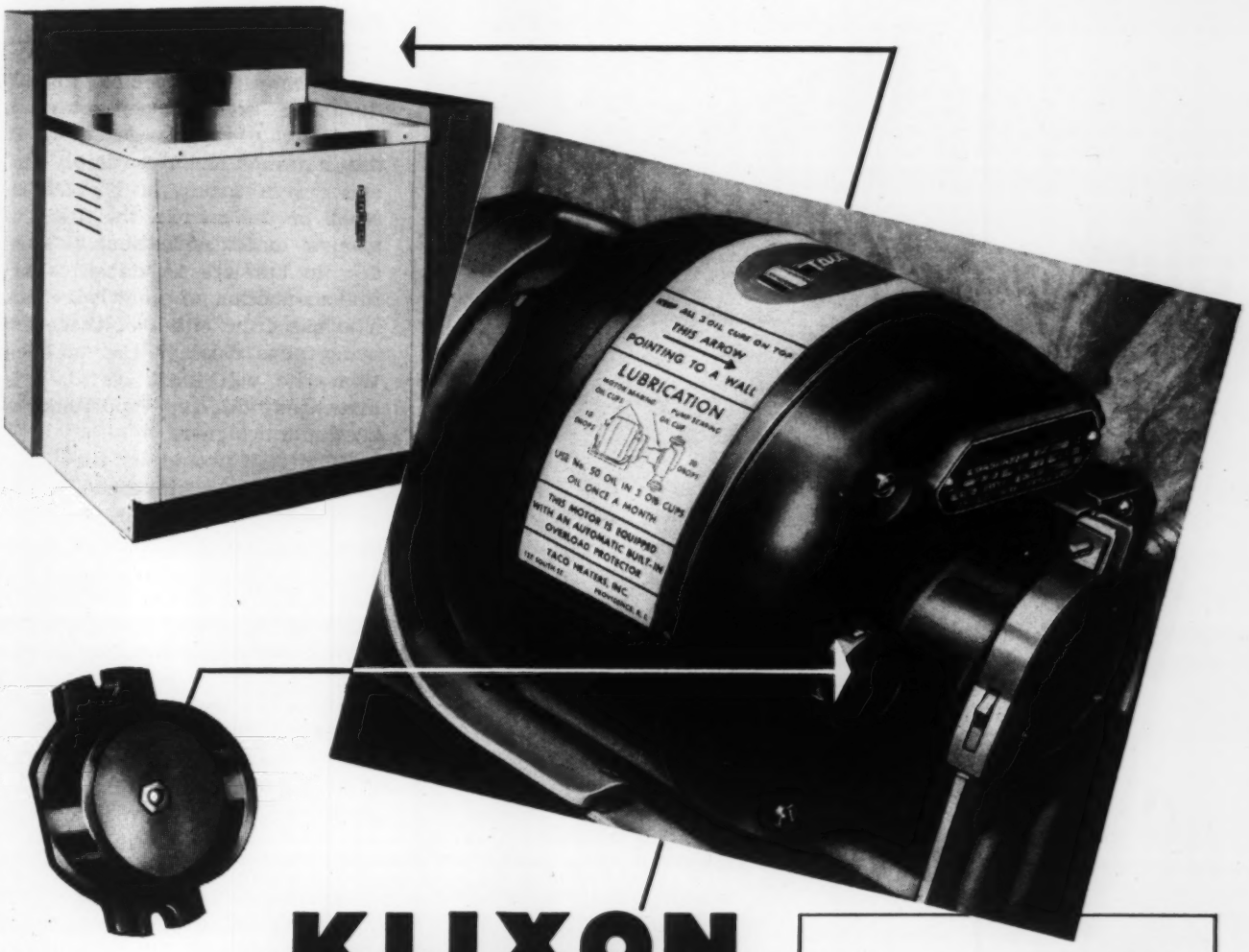
MEMBER OF AGMA




guage to be learned only by the comparatively few draftsmen who will be professional writers of it, but rather it must be thoroughly understood by all who are connected with technical industry.

It is virtually impossible for the engineer to be able to read without being able to write the language. It, also, must be a two-way street. There are those who believe that it is possible to read a drawing without being able to draw one. There are even some schools that offer courses in blueprint reading, presumably designed for mechanics. While these courses undoubtedly serve a useful purpose, and while it will be conceded that some people may be able to read a drawing without being able to draw one, it could well turn out to be a case of a little knowledge being a very dangerous thing. It is a situation in which no engineer can afford to place himself, since his is the responsibility for design and interpretation. To prepare himself for this responsibility, it would be desirable for the young engineer to enter industry by way of the drafting room.

**Personnel Classifications:** A good drafting room should probably be composed of four groups or classifications of people. One group may consist of men or women who have had little or no formal training, but because of a particular talent or liking for drafting have been brought in under some type of scheduled training program. Another group would consist of what may be called professional draftsmen. These are men who have chosen drafting as a profession and have prepared themselves for the profession at some technical school. These men are the backbone of the drafting room, the men upon whose shoulders rests the responsibility for putting into graphical language the ideas of the designer and the theoretical and practical solutions of the engineer. The third group may consist of graduate engineers who, initially, are much better equipped theoretically and technically than professional draftsmen, but would do the same type of work. It is this group, however,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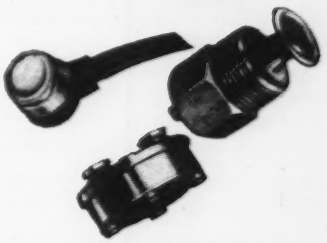

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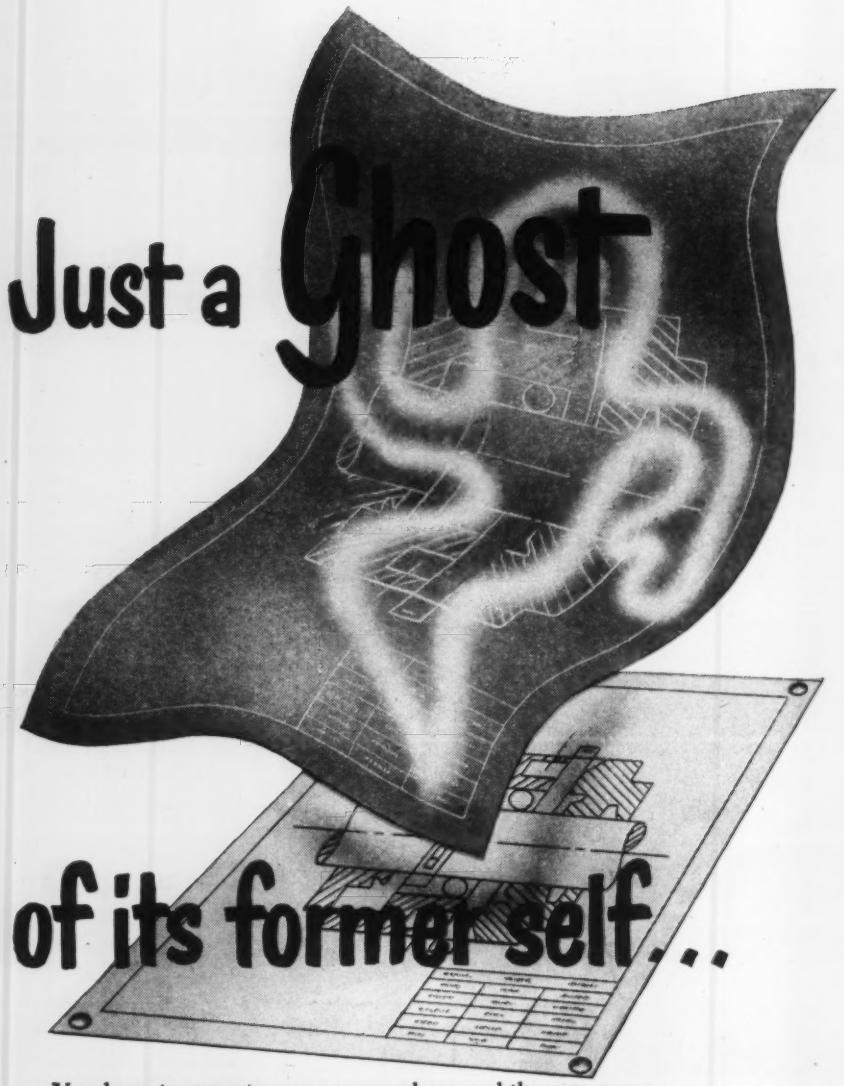


You have to expect some erasures here and there on your drawings. But watch out! When those drawings get to the blueprint stage, lines can become weak and washed out . . . just *ghosts* of their former selves.

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which may be expected to produce the greatest percentage of the fourth group, the designers. By this it is not meant to imply that the design group is beyond the reach of the men in the first two groups or classifications. There are no barriers to initiative and the acquisition of knowledge, and if a man from either of these first two groups displays the qualifications, he will most certainly be presented with the opportunity to become a designer.

Finally, it would be the design group which would create future design engineers. These are the men who, from training and experience, possess the knowledge and technique to develop the theory and tell others how to design the products of tomorrow. Because it is from here that all industry stems, it is the door to industry that offers the young graduate engineer the greatest opportunities for advancement.

Not too many years ago, when his services were not in such great demand as they are today, this was often the engineering graduate's only open door to industry. More recently, with the great shortage of engineering talent, industry has been forced to absorb young engineers into their organizations without this basic post-graduate training. While it is generally recognized that this procedure is not a desirable one for either industry or the engineer, it has been the lesser of two evils. An extended continuation of this procedure, however, may result in industry being staffed with engineers lacking one of the basic tools of the profession. The situation is analogous to eliminating the in-

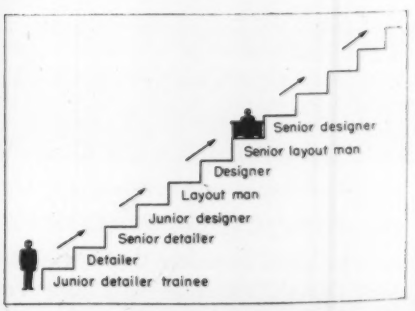


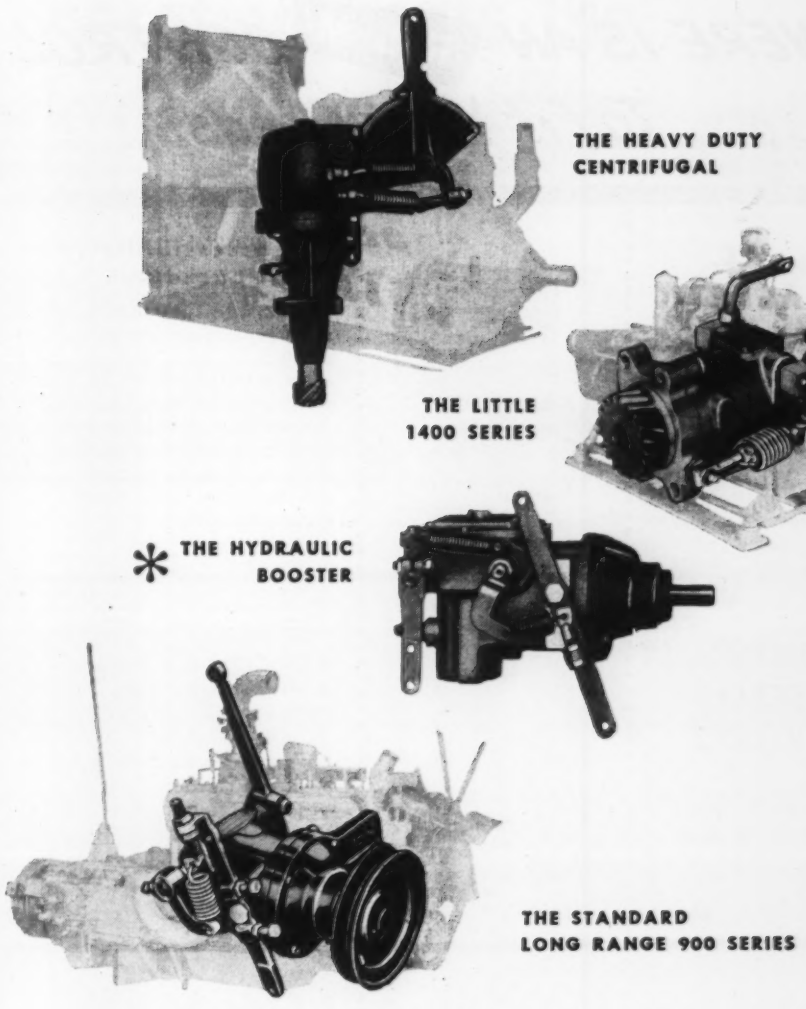

Fig. 1—Typical promotion ladder for an unlimited engineering career

ternship from the requirements of the medical profession. While at first the engineering graduate may feel that he has eliminated a rather unimportant part of his training and has immediately been placed in a position where he can use his talents to the best advantage, he may regret after a few years his lack of this basic tool. He may even have the unfortunate experience of seeing younger men so equipped steadily approach and surpass him in position and prestige. Therefore, it behooves both the engineering student and industry to take a long hard look at this situation; both have much to gain.

Theorizing upon and pointing out the disadvantages of shortcutting board work are desirable and necessary, but leave the situation none-the-less existent. To this end, most industries have instituted training programs of one sort of another in the hope that they will bridge this gap in the drafting room. Actually, these training programs and their administration have become one of the most important responsibilities of management.

**Drafting Room Operations:** Perhaps a good way to describe a typical drafting room would be to outline, in principle, how a trainee draftsman and then a professional draftsman would ultimately reach the status of a senior designer, a project engineer, or a position of higher level in engineering as shown in Fig. 1. It is assumed that the prospective trainee has had some training in mechanical drafting of high school level or higher, together with a genuine interest in this type of work. The training program as applied to the individual, of course, varies in detail depending upon the inherent ability of the trainee, his interest, the extent to which he applies himself to the acquisition of technical knowledge, his ability to work with others, and his personality characteristics.

Initially, the program should start with training in the blueprint vault. This acquaints him with the sizes and use of tracings, the filing and record systems, blueprint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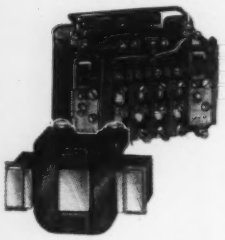

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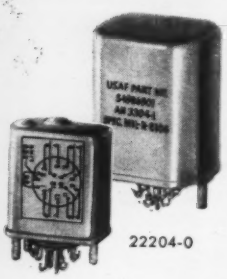


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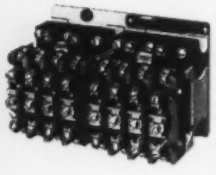

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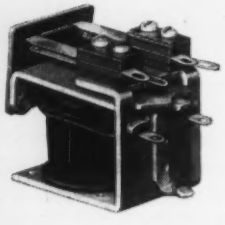

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operations and various tracing reproduction equipment. These things are all very important to the overall engineering department function even though they may not be immediately apparent to the trainee.

The second part of the program should include training in the engineering records department. Here is where he acquires a knowledge of the procedures and the necessity for new product releases, new drawing releases, change requests, change notices, methods of part number assignments for both experimental and production parts, and the distribution of prints to various departments. This phase of the work represents the business methods which are necessary to keep engineering records and to insure the prompt distribution of correct information to the various manufacturing and service departments of the company.

### Drafting Assignments

At the conclusion of these two preparatory periods, the trainee is assigned a drawing board and is given the opportunity to express ideas and instructions in the form of the engineering drawing. To begin with, the trainee's drawing assignments are strictly of an elementary nature, and he is constructively criticized by the checker and the chief draftsman.

As the trainee shows progress in his ability to make good elementary drawings accurately and quickly, he is given detail drawing assignments. This type of assignment involves progressively the drawing of simple and then complicated parts or groups of parts in assemblies.

Proficiency in this type of work leads to drawing assignments involving small layouts, and the trainee may be classified at this time as a junior layout man. It is at this time especially that he should be urged to acquire, either by himself or through formal training in night or correspondence school, a working knowledge of descriptive geometry, mathematics, strength of materials, mechanics, fabrication of materials, manufac-

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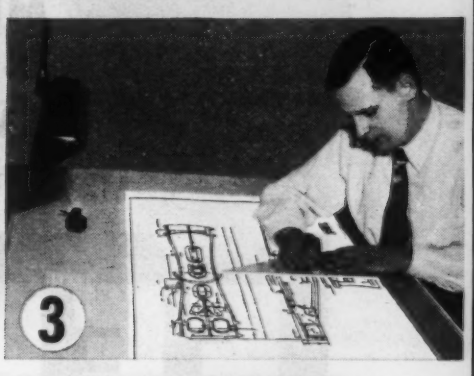


**A positive Repro-Negative** print is made from the corrected negative . . . on this the draftsman adds the new design . . . and a master is ready to produce the required number of prints. *Ready* in a fraction of the time required previously when the unchanged design was retraced in full.

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turing methods, and machine and machine tool operations. This type of knowledge, whether it is applied to a product to be manufactured, a tool, or a structure, makes the difference between an ordinary design and a good design, and is a prerequisite to further advancement. If this knowledge is not acquired directly by academic study, it must be acquired by the slower method of mistakes and eventual corrections. At this point in the trainee's career, his technical ability, his initiative, and his grasp of this method of engineering expression become increasingly apparent to the chief draftsman, the project engineers, and, in some cases, to the chief engineer. As he develops and acquires experience, the trainee becomes ready to assume the responsibilities of a senior layout man. It is at this point that the scheduled training program usually ends and the trainee is considered a professional draftsman.

### Designing the Product

The senior layout man has a wide opportunity to express originality and ability in design work, and the ultimate success of a manufactured product, a machine, or a structure is often determined on his drawing board. It is during this stage of his advancement that the draftsman becomes involved in engineering management within the drafting room. The degree of management varies, of course, with the individual.

The senior layout man may become a group leader and be responsible for the correctness and the application of the work of other men who are making detail drawings which form a part of an overall layout drawing. The senior layout man may become a checker, in which case he becomes responsible for the accuracy and adequacy of drawings to properly define the intended results. The senior layout man may become a junior and then a senior designer, in which case his talents may be used to collaborate with senior layout men and to work directly with the project engineers in starting new designs of products, or to

# your HORSEPOWER sense!

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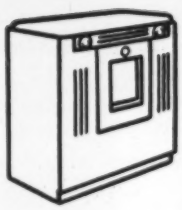

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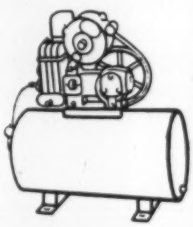
Check! Practically all of today's top-notch clothes dryers use one-third h.p. motors. But did you know that many clothes dryers are powered by Delco Motors? It's true . . . manufacturers of home appliances count on Delco dependability.



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Yes . . . all the above horsepower ratings are in use on water pumps . . . and Delco manufactures motors with each of these ratings. For use on rotary and reciprocating pumps. That's one reason why so many makers of pumps call on Delco for every motor need.

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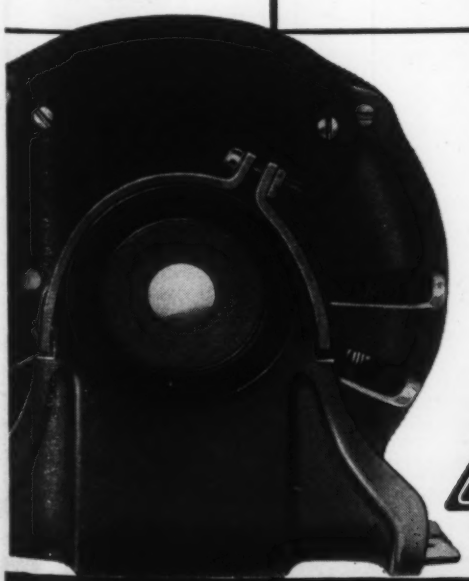
You win again. The vast majority of disposal units sold today are powered by one-third h.p. motors. One-third h.p. Delco Motors, that is! Disposal unit makers know from experience how Delco Motors stand up on the job . . . provide satisfying, trouble-free service through the years.



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create better and less costly methods and better and less costly designs of existing products.

The senior designer is the highest classification available to the draftsman, but instead of thinking of it as such, he should think of it as the ending of one phase and the beginning of another more promising phase of his career. It is his open door to opportunity and advancement to higher positions in engineering, manufacturing, inspection, sales or service, and eventually to management.

**Personal Outlook:** Draftsmen and designers are an essential part of our everyday existence. Every road, bridge, structure, machine, engine, household appliance, piece of furniture, piece of clothing, and practically everything else made for the use or comfort of man has at some time felt the influence of the draftsman. Moreover, as the universe and the natural laws that govern it become better understood, the man on the board becomes an ever more essential part of progress. Thus, any individual so engaged should view his personal efforts with pride in the realization that he is contributing his skill and services in a constructive manner for the benefit and advancement of society.

*From an article entitled "The Men on the Boards" appearing in General Motors Engineering Journal for June* 1953.

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By Norman A. Skow

*Director of Research*
*Synthane Corp.*
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**Just Push Tube Into Fitting Without Removing Nut**

The sleeve on Hi-Duty Fittings shears off during assembly and becomes permanently attached to tube. Fitting will make repeated tight reconnections.

**For Tubing ⅛" to ¾" O.D.**

**Ask for Bulletin No. 3002**

***Average Time Required to Assemble Fittings***

| Type of Fitting | Average Time Each Joint | Joints per Hour |
|---|---|---|
| HI-DUTY | 13.2 sec. | 274 |
| Regular Compression | 20.8 sec. | 173 |
| Flare | 45 sec. | 80 |

## Compared to COMPRESSION FITTINGS

Repeated, thorough tests under field conditions reveal that Imperial Hi-Duty Fittings can be assembled in an average time of 13.2 seconds . . . whereas regular compression type fittings take an average of *20.8* seconds. This is a *36%* saving in time . . . and precious labor.

## Compared to FLARED FITTINGS

Here the savings in time are even more striking since it takes *45* seconds on the average to install a flare fitting compared to 13.2 for Hi-Duty . . . a saving of *71%* in time. A man can assemble better than *3* Hi-Duty Fittings in the time it takes to assemble 1 flare fitting.

***Why is the HI-DUTY FITTING so much Easier and Quicker to Assemble?***

**Fitting furnished with integrated nut and sleeve**

To get a tight joint, simply insert tube into fitting and tighten nut. No loose sleeve to drop . . . no flaring required. Makes repeated tight reconnections.

## MAKES STRONGER JOINTS

Because sleeve is always in perfect alignment when joint is made and because its design minimizes deformation of tubing, Hi-Duty Fittings assure stronger joints that remain leakproof even under severe service. Tests show Hi-Duty joints will stand over 5 times as much vibration as joints made with ordinary compression or flare fittings.

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on plastic boards, by spraying metal into depressions in a plastic plate, by bonding rigid wiring harness to a plastic base, by fusing silver ink patterns on ceramics, or by etching of metal-clad plastics. The latter method is currently gaining in popularity and seems to be admirably suited to the mass production assembly procedures in the electronics industry.

**Materials:** The electrical properties of printed circuits are largely determined by the base laminate, the metal foil, and the adhesive used to bond the two. For most printed circuit applications, copper foil in a variety of thicknesses is bonded under heat and pressure to one or both sides of thermosetting laminated sheet stock of the desired grade and thickness.

Numerous experiments have been made to determine the suitability of copper, aluminum, brass, and silver foils. Of these, copper has been the most widely used; however, other metals are rapidly gaining in popularity. Silver and brass possess excellent current-carrying characteristics but suitable adhesives have not been developed which can produce a bond sufficiently strong for most service conditions. On the other hand, aluminum bonds well but poses a number of problems in soldering techniques. A partial solution to the soldering difficulty has been accomplished by using a thin layer of copper or tin alloyed to one surface of the aluminum foil.

For printed circuit applications, electrolytically deposited copper foil is preferred over that produced by the rolling method. The foil is electrolytically deposited as a thin layer on a smooth, revolving lead drum and when it is stripped off one side is extremely smooth while the other side is relatively rough. This smooth side permits uniformity of etching while the rough side becomes an ideal surface for bonding. For use in printed circuits quality control must be rather rigid. Foil thicknesses of 0.00135 and 0.0027-inch are most commonly used.

The most satisfactory printed circuit dielectrics or insulating ma-

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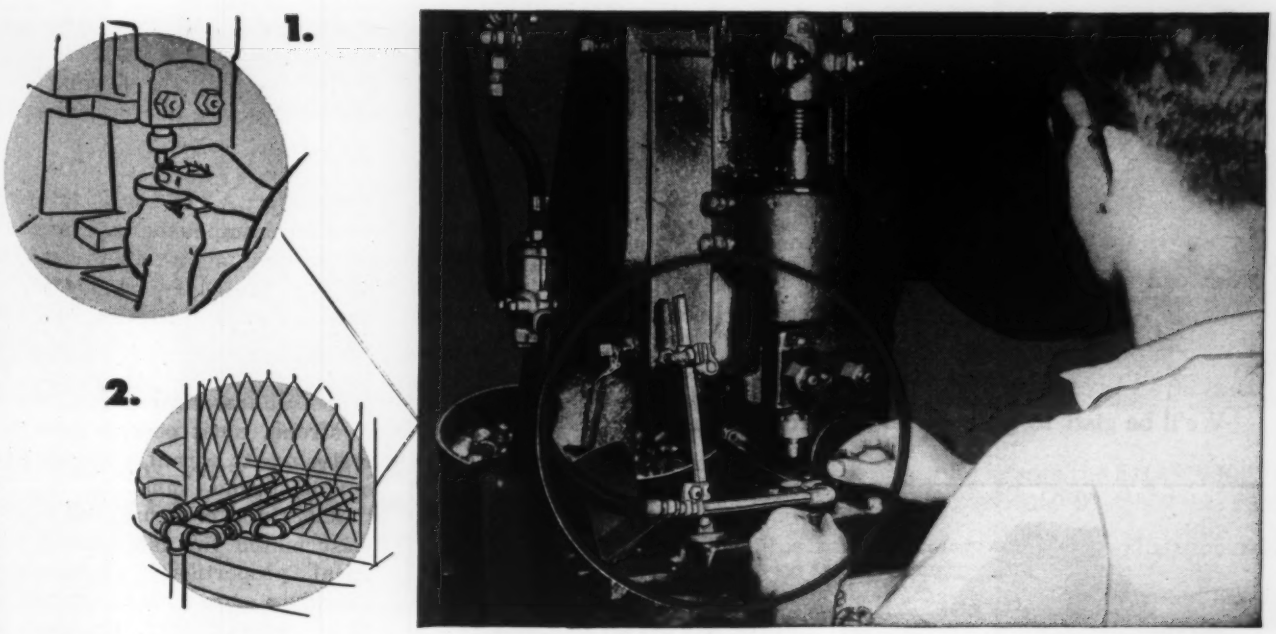


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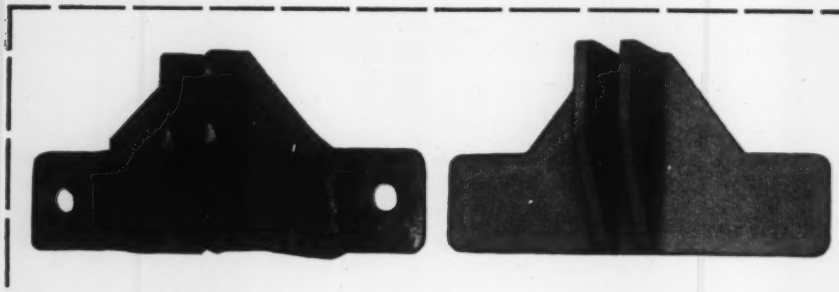

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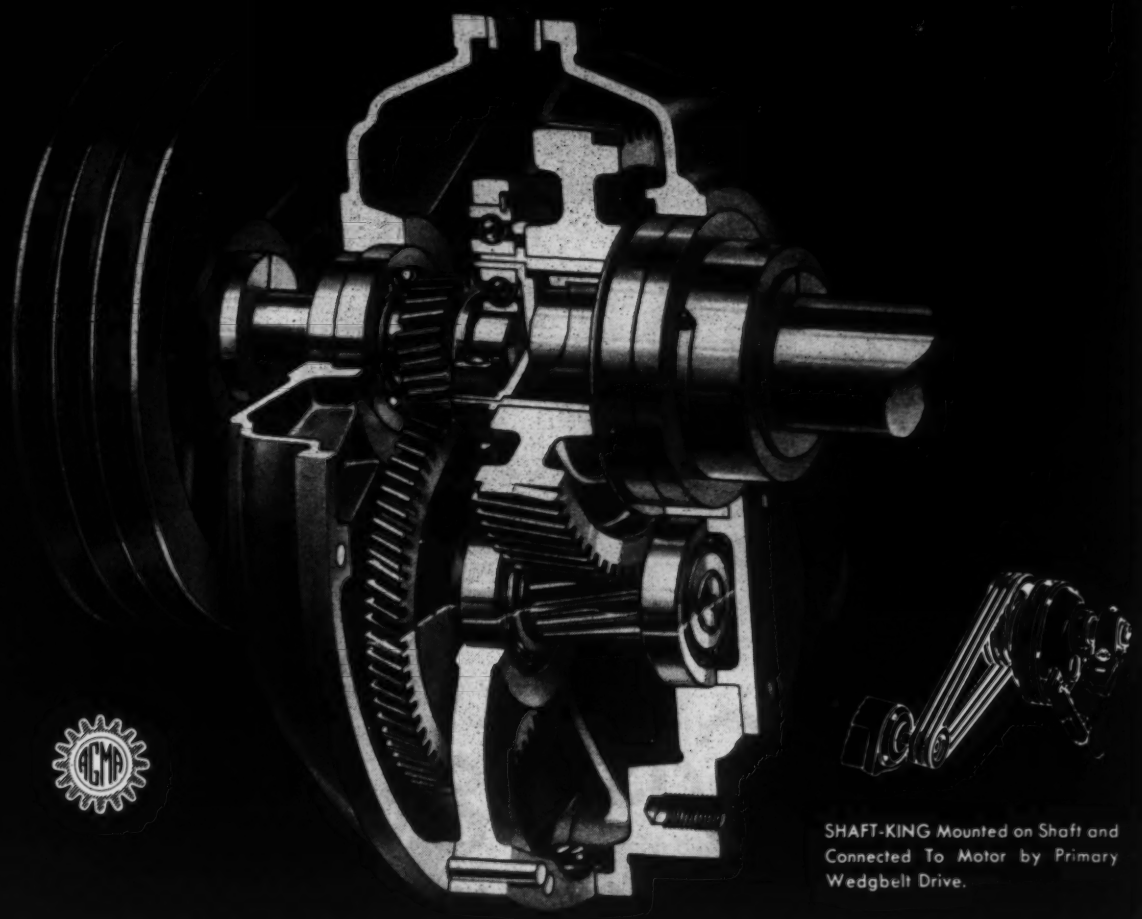
terials developed thus far are the thermosetting laminated plastics. Any of the 20 standard grades of thermosetting laminated products described in the National Electrical Manufacturer's Association *Standards for Laminated Thermosetting Products* (Publication No. LP1-1951) will produce a satisfactory bond with copper. The most satisfactory insulating or dielectric material in general use today is NEMA Grade XXXP. The ensuing chemical reaction transforms the layers into a hard, dense solid which will not delaminate and cannot be resoftened by the application of heat. Even in thin sheets, XXXP grade combines excellent electrical properties with the good machinability so necessary for punching operations.

Laminates other than phenolics, such as melamine and silicone may also be used. Melamine resins are used where arc resistance is an important factor, and silicone resins are used when heat resistance is required.

**Bonding:** A great number of proprietory compounds are available for bonding metal foils to base laminates. These compounds include phenolic, melamine, urea, and vinyl resins. Adequate bonding, however, is a formidable problem. The proper adhesive must be sufficiently strong, must possess good heat resistance to permit soldering without blistering, must be resistant to shock and moisture, and must at least match the laminate in electrical properties. Thermoplastic adhesives are characterized by their susceptibility to blistering during soldering operations and also have too much cold flow under normal operating conditions. On the other hand, common thermosetting adhesives do not possess the required shock resistance and do not bond the copper foil as well as desired. This problem has been solved by developing specially formulated mixtures of both thermosetting and thermoplastic resins.

The actual mechanics of bonding foil to a laminate may be accomplished by one of two methods. Class 1 copper-clad laminate is produced from a predetermined num-

# NEW! SHAFT-KING Speed Reduction Drive



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4. Leakproof: Anti-friction oil sealing system keeps air in—dirt out.
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**LEBANON Castings**

CARBON, SPECIAL ALLOY AND STAINLESS STEEL

CIRCLE L


## Design Abstracts

ber of resin-impregnated sheets to which is added a thin, dry sheet of adhesive film followed by a sheet of copper foil. The entire build-up is then subjected to heat (approximately 320 F) and high pressure (approximately 1000 psi) for about one hour. If desired, the adhesive film and foil may be added to both sides of the build-up.

The more expensive Class 2 copper-clad laminate is designed to meet closer thickness tolerances than Class 1 material. It is produced by sanding a finished, cured sheet of laminate to the desired thickness, after which the adhesive and copper foil are added. It is then returned to the press for a second application of heat and pressure.

After bonding, copper-clad sheets are usually sprayed with a strippable plastic film for protection against scratching, oxidation and scarring.

**Properties of Copper-Clad Sheets:** The principal requirements for finished sheets of foil-clad laminated materials are their ability to resist peeling, heat, and moisture. Other important considerations are that the copper surface be substantially free of wrinkles, pits, nodules, scratches, pin holes, and oxidized areas. It must be uniformly thick otherwise it would be impossible to etch fine lines. The copper must be relatively soft in order to retain proper punching characteristics.

The adhesive layer must possess good electrical properties and be resistant to moisture. When bonded it becomes an integral part of the sheet of dielectric and must match the selected grade of laminate in NEMA characteristics.

A quality control check on the laminate is made to determine the water resistance and dissipation factor at one megacycle after immersion in water for 24 hours at room temperature. These tests are made according to procedures designated by American Society for Testing Materials.

Bond strength varies with the thickness of the copper. For copper 0.00135-inch in thickness the bond varies from 3 to 5 pounds. For copper 0.0027-inch in thick-

ness the bond varies from 4 to 6 pounds.

**Assembly:** Methods of assembly of printed circuits into finished electronic or electrical devices are as varied as the applications. The most obvious method is to simply punch or drill holes through the conductor and the laminate, inserting leads of standard components into the holes and soldering the leads to the conductors. Complicated circuitry is normally laid out on both sides of the piece to provide for crossovers. Connections between conductors on opposite sides may be made by component leads, tinned eyelets, rivets, pins, or simply short lengths of wire. With the proper laminate, components can be unsoldered and resoldered several times before foil shows a tendency to lift from the base.

Dip soldering has proven practical as an assembly technique for smaller units. With all of the circuitry placed on one side of the dielectric, holes about 0.040 to 0.045-in. in diameter are punched or drilled to take the leads of resistors, capacitors, subminiature tubes, etc. All of the components are placed in position on the opposite side of the piece from the etched pattern, with their tinned leads inserted through the holes. Usually the conductors are fluxed prior to this operation with a noncorrosive resin-type flux. All the necessary connections are then made between the components and the conductors by a single short dip in a molten solder bath. After dipping, excess lengths of the protruding leads are trimmed off.

**Production Economy:** Printed circuits are practical principally because of their simplicity and uniformity. They are particularly adaptable to complex commutators and switching networks where subminiaturization is required. Elimination of manual wiring speeds assembly and inspection time is automatically shortened while assemblies become more uniform and reliable.

*From a paper entitled "Metal-*

biological specimens
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MICROTOME
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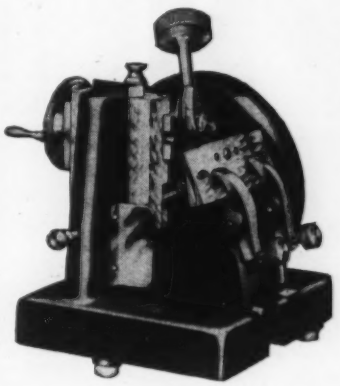

International Equipment Co., Boston, Mass., manufactures the Microtome shown and other precision instruments. For the Microtome, they chose Hitchiner precision investment stainless steel castings because they could get extremely accurate parts with a minimum of machining. These castings also lend themselves to the very high, bright, smooth finish necessary on instruments of this quality.

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## Design Abstracts

*Clad Laminates Used in Printed Circuitry" presented at the Spring Meeting of the ASME in Columbus, O., April* 1953.

## *Improving Gear Design with Shot Peening*


By John C. Straub

*Chief Research Engineer*
*American Wheelabrator & Equipment Corp.*
*Mishawaka, Ind.*

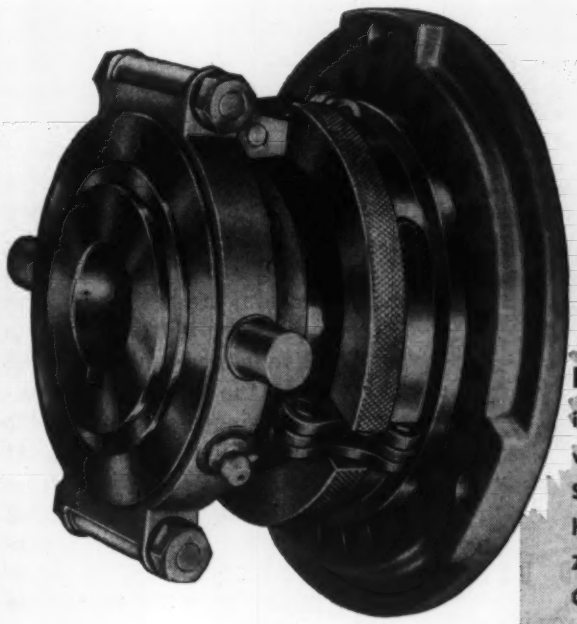

SHOT PEENING is a process which might well be considered in the design of any machine part which is required to carry high loads with a minimum size or weight of the overall unit. Briefly, it is a process utilizing the impact of metallic shot for the purpose of setting up a layer of compressive stress in the surface of a metal part. This compressive stress in the surface is very effective in increasing the fatigue strength of that part.

The type of machine parts to which shot peening is applied in production for increasing life or load carrying capacity extend all the way from small springs to locomotive bull gears, and include almost every conceivable type of spring; axle shafts, torsion bars, propeller shafts, crank shafts; connecting rods and other engine parts; chain links, universal joints; spur, helical, and bevel gears; steering knuckles and almost every type of part in which fatigue failure is recognized to be a problem. Materials peened include steel of various hardnesses, iron, aluminum and its alloys, brass, bronze and magnesium.

There are many instances in which gears of various types are peened in regular production. Practically all of the major automobile manufacturers use shot peening for gears and other machine parts. The aircraft industry also uses the process quite extensively in the manufacture of parts and components.

There are a large number of applications in which the addition of shot peening to a given design has permitted the successful continuance of that design in production,

# Check JOHNSON single disc a Better CLUTCH for the same money



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**BECAUSE . . .**

**it's the only clutch with SEPARATOR SPRINGS that prevent heating in both HORIZONTAL and VERTICAL installations.**

For some time there has been a demand for a single disc clutch for positive control of power transmission in the field of light machinery . . . a clutch that would stay cool on the job in both horizontal and vertical installations. This is "it."

If extreme compactness is not an essential, the Johnson No. 350 (3 h.p. max.) and No. 450 (6 h.p. max.) will meet or beat competition . . . as a better clutch at a competitive price. They incorporate most of the design principles of our Maxitorq multiple disc . . . and except for compactness and capacity, you will find them tops in their field. (Please read column at right . . . "Frankly Speaking" . . . for use recommendations.)

Several driving combinations are available, including V-belt. A simple hex key frees the knurled ring for easy manual adjustment. The "floating" disc prevents drag, abrasion, and heating in neutral. Machine and product designers will solve many problems in the light machinery field with this new Johnson single disc Clutch.

**Send for Bulletin No. 250-MD-9**

**THE CARLYLE JOHNSON MACHINE CO.**
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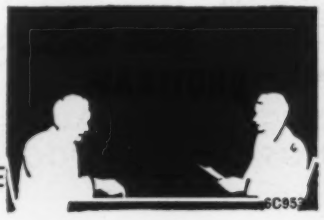


## Frankly SPEAKING

Because of a large backlog of orders, The Carlyle Johnson Machine Company found it necessary to postpone the announcement of the new Johnson Single Disc Clutches.

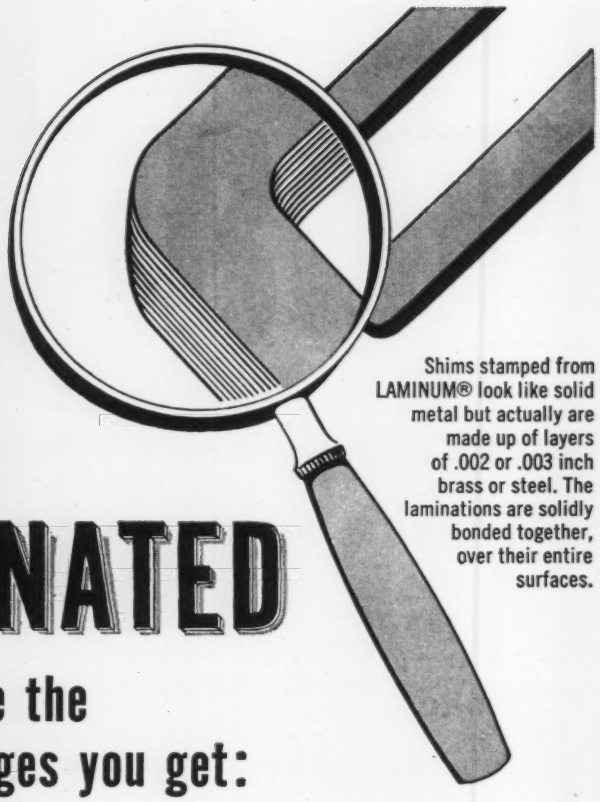
Now, with added equipment for high speed production, it is possible to produce and ship the new clutches without undue delay. In fact, small orders or units for try-out in new machines will be forwarded at once. Design features make the Johnson especially suitable for installation in the following machinery:

Accessory Drives, Air Compressors, Bag Making, Boat Drives, Bread Wrapping, Chain Drives, Combines (farm), Conveyors, Crop Seeders, Cultivators, Dusting Machines, Feed Grinders, Floor Scrubbing, Fruit Cleaners, Gasoline Engines, Generator Drives, Hay Balers, Hoists, Loaders, Lawn Mowers, Milk Coolers, Mixing Machines, Motor Scooters, Packaging Machines, Paper Shredders, Power Fans, Power Saws, Power Take-offs, Pumping Equipment, Sand Spreaders, Sewing Machines, Sheep Shearers, Spraying Equipment, Textile Machinery, Threshers (small), Tobacco Machinery, Tool Grinders, Tractors (garden), V-Belt Drives, Vegetable Sorters.

Naturally, these are but a few of the possible applications for the Johnson Single Disc Clutch. The field is wide open, with new machinery constantly being developed.

Included in the driving combinations are: Gear Tooth, Bolted Plate, Pulley Type, Hub Adapter, Cut-off Coupling Adapter, Single V-Belt Pulley Drive, and Double V-Belt Pulley Drive.

Carlyle Johnson engineers offer their engineering assistance in cooperation with your engineers and machine designers to develop the correct solution of your power transmission requirements. Write to Frank R. Simon, The Carlyle Johnson Machine Co., Manchester, Conn.



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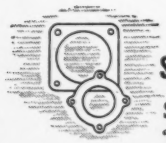

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**SPEEDED PRODUCTION:** Final fitting can be done right at the job. You don't have to take parts back and forth for further machining, grinding or filing. No special skill required. The laminations adjust spacing quickly, easily.

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## Design Abstracts

in spite of greatly increased load carrying requirements. This seems to clearly illustrate the adaptability of the same process for use in the original design of machine parts in which the advantage of increased fatigue strength can be realized.

**Fatigue Strength:** When shot peening is considered in the design of a pair of gears, one of the first questions which arise is "How much increase in the allowable bending stress can be obtained by the process?" This is not a constant value, but depends upon the order of magnitude of the working stresses involved. Or, to put it another way, it will depend upon the required useful life of the gears at maximum load. Shot peening is not effective in increasing the static strength of the material, but becomes increasingly effective as the required useful life is increased. At a life of 100,000 cycles, the increase in allowable stress due to peening is about 10 per cent over a non-peened gear. However, at a required life of 1,000,000 cycles, the increase in allowable stress is a little more than 25 per cent. At a required life of 10 million cycles, the increase in allowable stress is close to 50 per cent.

It should be emphasized that the figures just quoted represent the increase in *allowable stress* for a given life as distinguished from increase in life at a given stress. The increase in life at a given stress is much greater. For example at a stress of 80,000 pounds per square inch the increase in average life resulting from shot peening is approximately 1000 per cent.

**Weight Reduction:** In gears which are subject to fatigue failure due to bending stress, the maximum stresses are located at the tooth fillets. It might appear that the possibilities of reducing weight by shot peening are meager. This is not necessarily the case. For gears of similar geometry, the maximum bending stress in the tooth fillet will vary inversely by approximately the cube of the pitch diameter, or the cube of the center distance. A decrease in center dis-

*REO DESIGN ENGINEERS SAID...

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Reo engineers needed *top performance* from this new drive shaft . . . so they insisted on STRESSPROOF! They knew from years of successful experience with STRESSPROOF that it could take abuse. It had both the strength and wearability to stand up under the toughest service—and its excellent machinability was most welcome from a cost standpoint.

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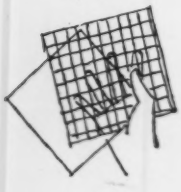

#2. Some wire cloth producers can work in only a certain few metals or in a limited range of mesh sizes. Here at Cambridge we can weave cloth from any metal that can be drawn into wire...our range of sizes runs from 20 x 250 mesh up to 4 inch openings ...a BIG advantage for customers with varied needs.

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tance, of course, means that the size of the entire housing can be decreased in proportion.

The weight of a spur or helical transmission will vary by approximately the cube of the center distance, other conditions being constant. This means that, in cases where bending strength is the controlling factor, if the allowable bending stress is increased, the weight of the unit can be reduced in the same proportion.

**Scoring:** The fact that shot peening is most commonly used as a means of increasing fatigue strength in bending or torsion does not mean that the process should be ignored in a gear design which may be subject to scoring. Data available indicate that shot peening has little direct influence on scoring or pitting. However, when the overall design of a pair of gears is considered, it will be recognized that bending strength sometimes conflicts with scoring resistance. For example, a coarse pitch is favorable for bending strength because of the greater thickness at the root of the tooth. However, due to the greater tooth height necessary for adequate tooth contact ratio, assuming the same pressure angle, tooth action will take place closer to the base circle, with a consequent decrease in the radius of curvature. This results in a higher compressive stress both at the beginning or end of action, and at the highest point of single tooth contact. Also, as a result of the greater tooth height as well as greater normal pitch, the sliding velocity will be greater with a coarse pitch than with a fine pitch.

This leads to the conclusion that although a coarse pitch is favorable for bending strength, a fine pitch is favorable for scoring resistance. But if shot peening is considered in the design of the gears, it can be employed to permit the use of a finer pitch for greater scoring resistance by providing the necessary increase in bending strength. Carrying this concept somewhat further, shot peening may be used to accomplish a decrease in size of the gears, even though the application may be

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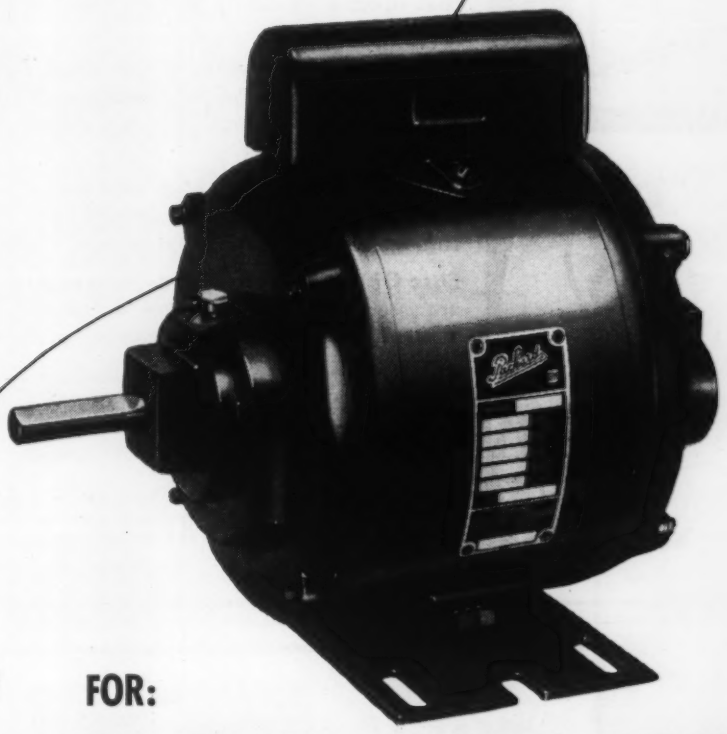

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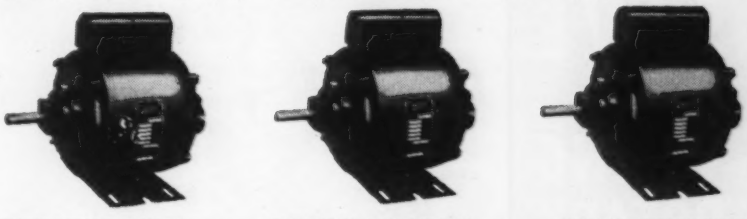

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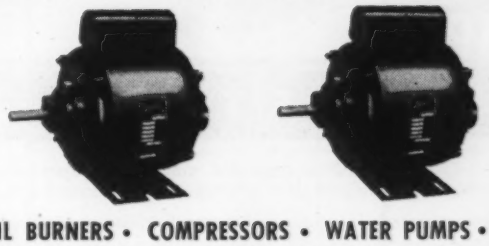

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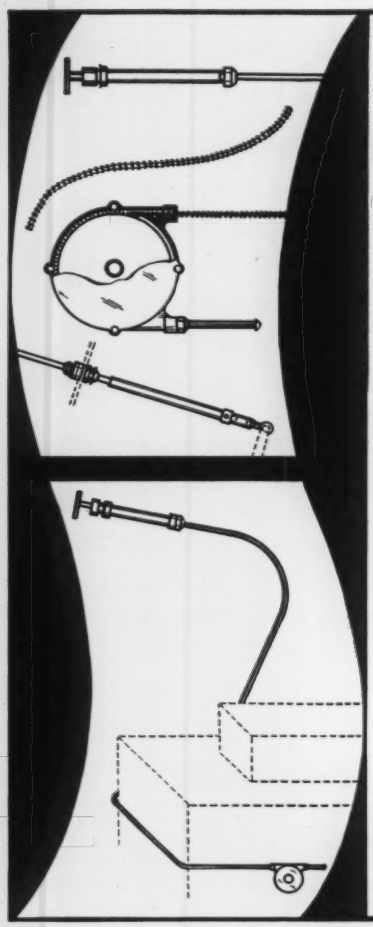

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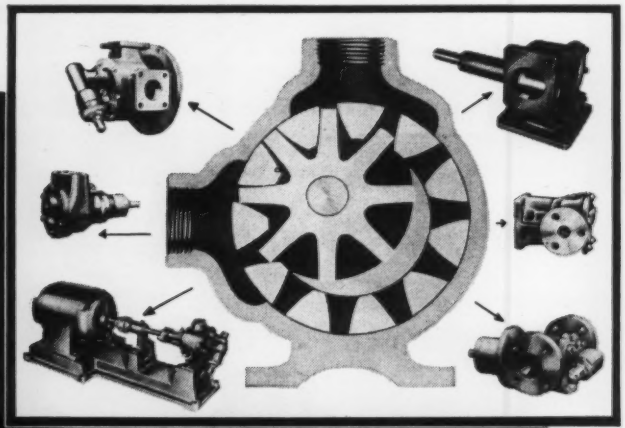

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## Design Abstracts

more vulnerable to scoring than to bending failures, provided the design with peening is balanced for equal resistance to scoring and bending failures.

**Pitting:** In cases of high ratio gears in which tooth action approaches the base circle of the pinion, the compressive stress might be very high because of the small radius of curvature in that region. This naturally suggests the use of long and short addendums, but even then the high compressive stress might present a problem. This condition again suggests the use of a finer pitch, which in the case of very high ratios may not permit a further decrease in the gear addendum, but it would permit a greater contact ratio for better distribution of the transmitted load. In more moderate ratios, in which pitting is more likely to occur just below the pitch line of the pinion, the benefit of a finer pitch would probably be less than in the case of high ratios, although it would result in a slight increase in contact ratio for full depth teeth.

**Gear Noise:** The question sometimes arises, "Is there a sufficient dimensional change from peening to introduce errors in gear tooth profile?" With proper peening procedure, there should be no significant change in profile, particularly in hardened gears. Some manufacturers have compared the noise level of peened gears against identical gears nonpeened, and were unable to detect any difference in the noise level. At least one manufacturer insists that shot peened gears are more quiet in operation. Both of the cases cited are related to carburized and hardened gears.

In most cases of gear production, peening is the last operation insofar as the teeth are concerned, and no attempt is made to protect the tooth profiles from the blast. However, in some cases the gears are cut with a protuberance hob to provide an undercut at the roots of the teeth. The gears are then hardened, shot peened and ground. In large gears, this procedure allows the tooth profiles to be ground without removing any of the shot

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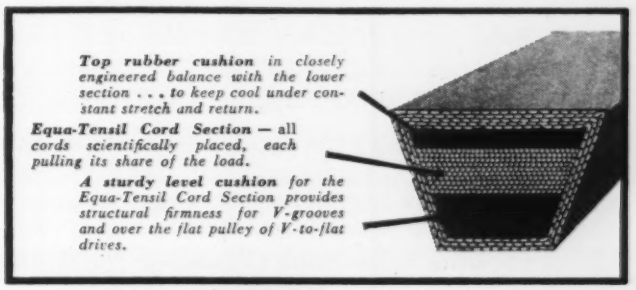
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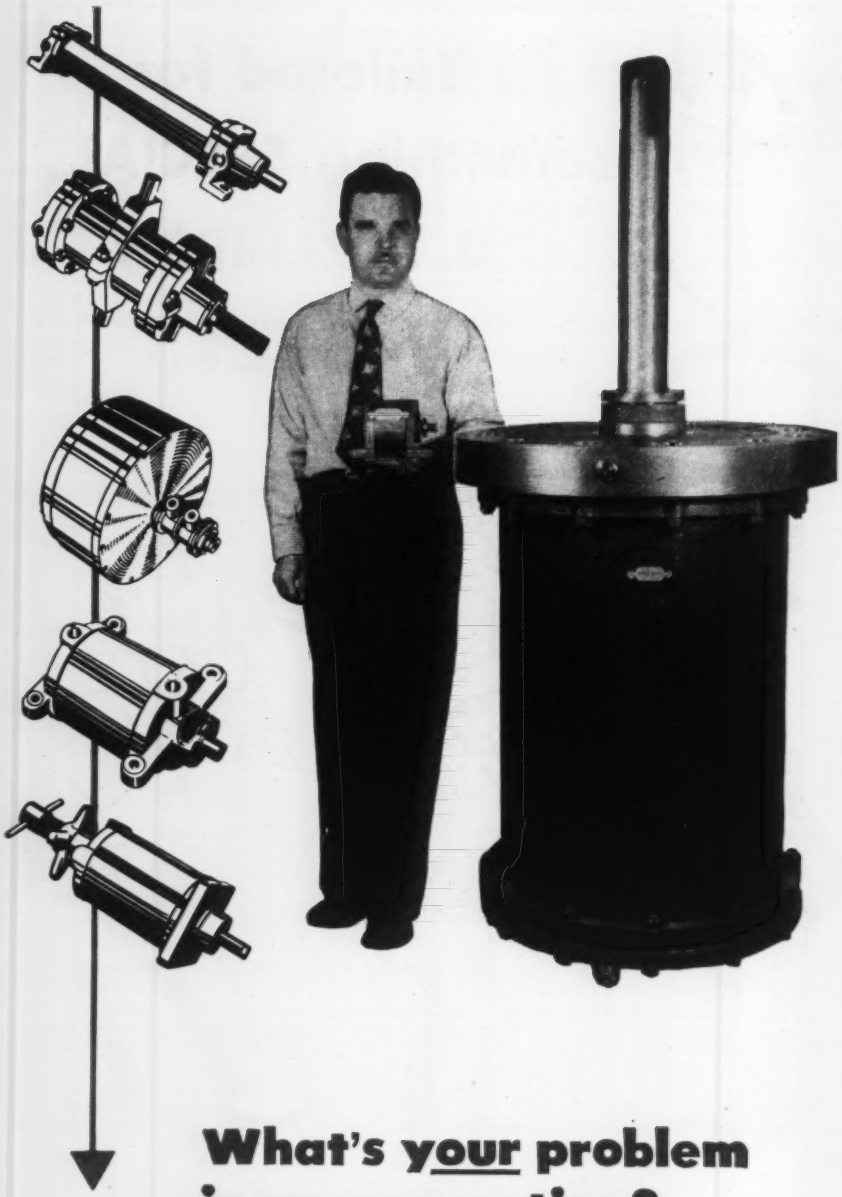

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peened surface in the fillet where the bending stress is maximum. This provides a means of overcoming distortion in heat treatment, and also a ground profile where this is considered essential.

**Control of Shot Peening:** Shot peening is controlled by means of a standard Almen test strip of spring steel which is subjected to the peening blast in the same program as the work, and then measured for the degree of curvature resulting from the blast. A standard test strip holder is used for holding the strip during peening.

In setting up a peening job, it is necessary to specify the peening requirements on the basis of full sized shot if efficient operation is to be obtained. Any broken shot which is allowed to remain in the machine is completely ineffective in increasing fatigue strength beyond that which is obtained with the full sized shot alone. A peening machine should be equipped with a separator capable of removing broken or undersized shot in continuous operation. Of equal importance is the provision for uniform replacement of the broken shot with new shot.

For efficient operation it is also important that the shot strike the work as nearly as possible at right angles to the surface in the region of maximum stress in service. Any shot which strikes the work at an angle appreciably less than 90 degrees is ineffective in the same way as undersized shot.

**Arc Height:** In setting up specifications for shot peening, the arc height should be established in relation to the thickness of the part at the location of maximum stress, and the overall requirements of the particular job. It is not feasible to set down a hard fast rule for arc height, because of widely varying requirements. Wherever possible, it is good practice to establish, by fatigue tests on shot peened parts, the range of arc height most suitable for the particular application.

**Coverage:** For efficient operation, coverage should also be considered in relation to the require-

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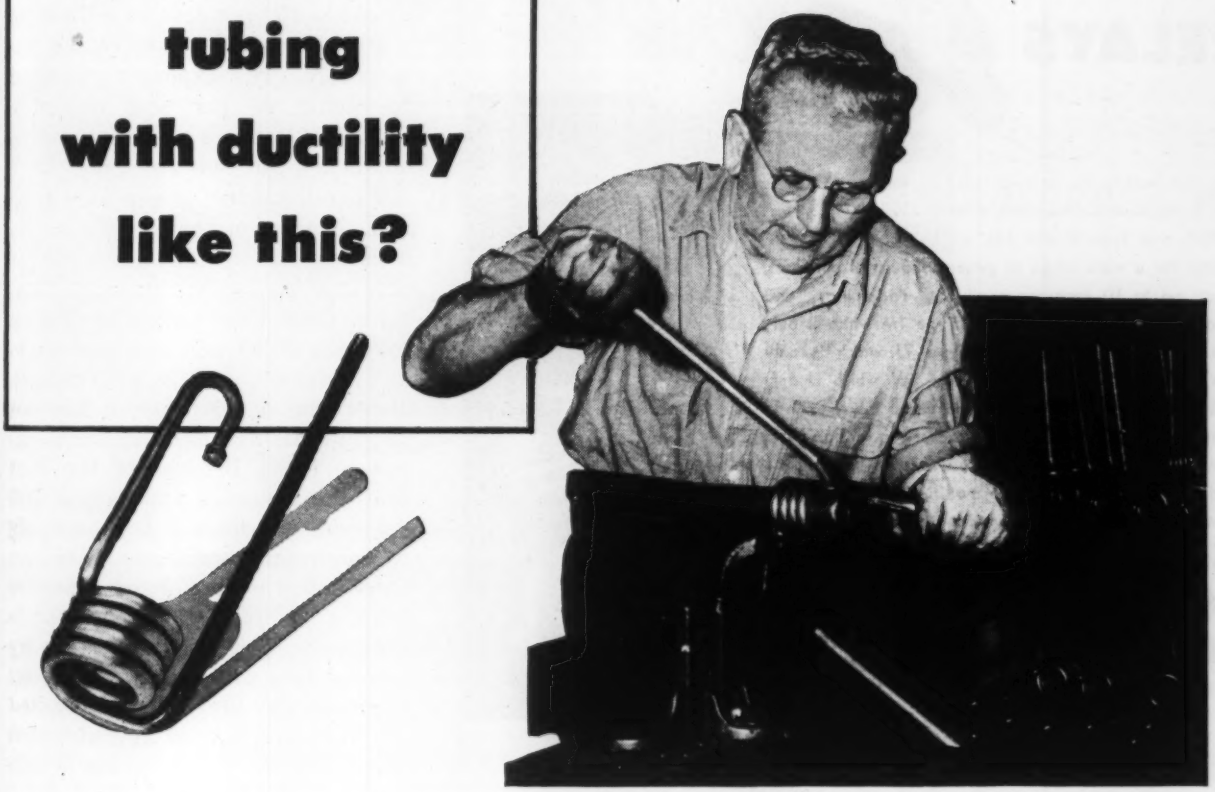

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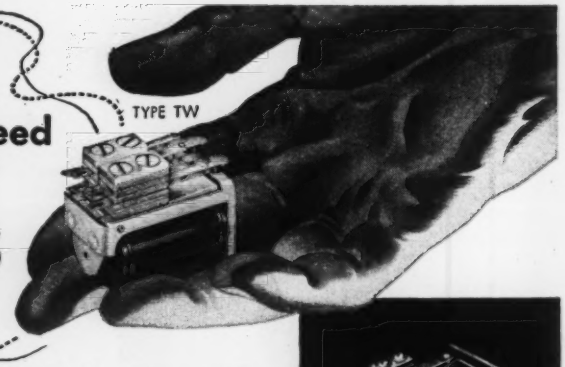


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## Design Abstracts

ments of the job. Coverage may be defined as the proportion of a given area of the work which has received direct impact of the peening blast.

Theoretically, coverage approaches 100 per cent as a limit as the exposure time is increased indefinitely. The exposure required to obtain 98 per cent coverage is about 2½ times that required to obtain 80 per cent coverage.

The relationship of exposure time and coverage naturally raises the question as to the influence of coverage on fatigue strength. Fatigue tests have indicated that a coverage of 98 per cent results in an increase of fatigue strength above that of 80 per cent but not in proportion to the additional exposure time. Because of the fact that the coverage approaches 100 per cent as a limit, it is reasonable to believe that additional life can be obtained by prolonged exposure after a coverage of 98 per cent is obtained. This is supported by fatigue data which show a gradual increase in life with increased coverage well beyond that at which there are no visible areas which have not been indented.

**Choice of Shot Size:** The choice of shot size for a peening operation will depend upon the arc height and coverage required in the particular application, with due consideration for sharp corners or fillets. The usual rule in this case is that the nominal diameter of the shot should not exceed the radius of the fillet. Fatigue tests have indicated that for a given coverage and arc height, other conditions being the same, the same increase in fatigue strength can be obtained with one shot size as with another, with due consideration to shot velocity.

Since the number of pellets per pound of shot varies inversely as the cube of the diameter of the particles, it is only natural that coverage is obtained at a much higher rate with smaller shot. This of course implies that in order to obtain the same arc height with the smaller shot, it is necessary to increase the shot velocity. However, in spite of the fact that the rate of shot usage increases rapidly with shot velocity, the increased

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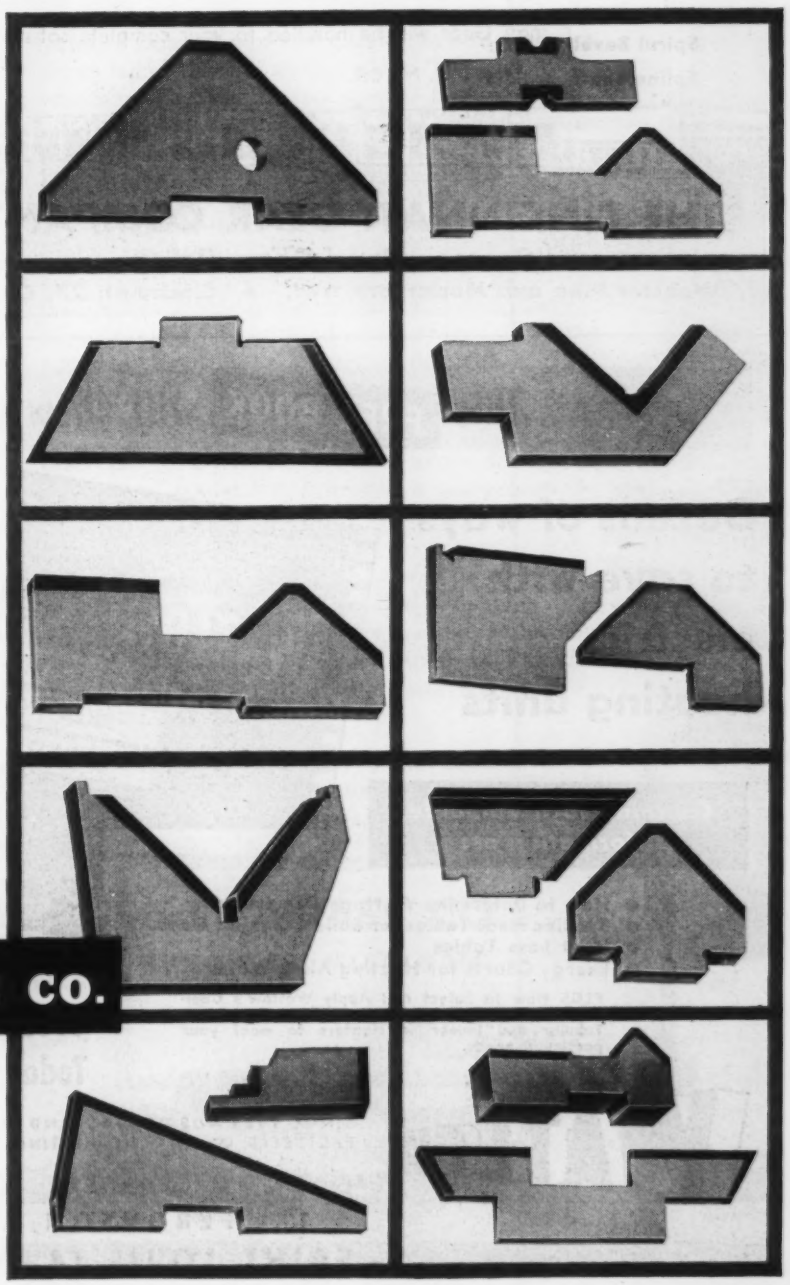

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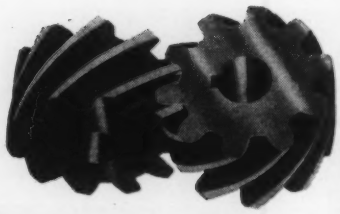

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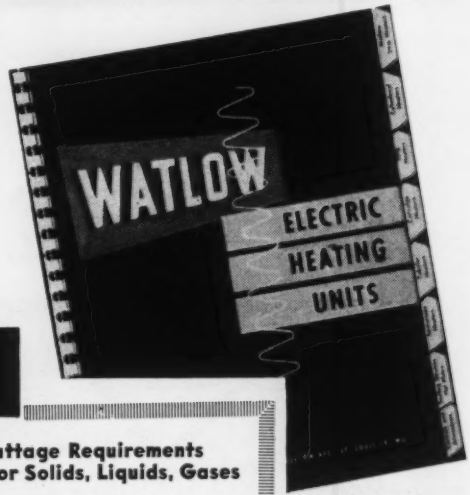


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## Design Abstracts

production resulting at the higher conveyor speed compensates for the rate of shot usage so that the shot usage per unit of production is approximately the same. The net result is that with the smaller shot higher production rates are obtained with no increase in cost of operation.

**Type of Shot:** For several years, it was considered necessary that the hardness of the shot should be at least equal to that of the work being peened. Under these conditions, chilled iron was the only type of shot used for peening fully hardened work. Since the advent of steel shot, however, fatigue tests have shown an equal increase in life for fully hardened parts (60 Rockwell C) when peened with chilled iron shot and with steel shot having a hardness in the neighborhood of 45 Rockwell C. This is a distinct advantage because the rate of usage with a good quality steel shot is a fraction of that with chilled iron shot. It is important, however, that the hardness of steel shot is not appreciably less than 45 Rockwell C. Any shot which is appreciably softer is ineffective in the same sense as broken shot. Even for work with a hardness of 40 to 45 Rockwell C, a wide range of hardness in the shot results in an inefficient blast because the softer particles do not add to the work done by the harder particles.

**Shot Peening Equipment:** For uniform results, the work should pass through the blast in a mechanically controlled cycle to insure that all surfaces subject to high repetitive stresses are uniformly covered by the blast. For low volume of production, or in some particular cases where only a small area of a relatively large part is to be peened, an air blast might be sufficient. However, for high rates of production the airless method involving a rotating bladed wheel is more practical and economical.

*From a paper entitled "Shot Peening in the Design of Gears" presented at the Annual Meeting of the American Gear Manufacturers Association in Hot Springs, Va., June,* 1953.

# Meetings

## AND EXPOSITIONS

**Sept. 13-17—**

**Electrochemical Society Inc.** Fall meeting to be held at the Ocean Terrace Hotel, Wrightsville Beach, N. C. Dr. Henry B. Linford, 235 West 102nd St., New York, N. Y. is secretary.

**Sept. 20-23—**

**Packaging Machinery Manufacturers Institute.** Twenty-first annual meeting to be held at the Skytop Lodge, Skytop, Pa. Additional information may be obtained from society headquarters, 342 Madison Ave., New York 17, N. Y.

**Sept. 21-22—**

**Steel Founders' Society of America.** Fall meeting to be held at the Homestead, Hot Springs, Va. Additional information may be obtained from society headquarters, 920 Midland Bldg., Cleveland, O.

**Sept. 21-25—**

**Instrument Society of America.** Annual meeting and joint conference with the Industrial Instruments and Regulators division of ASME to be held concurrently with the eighth national instrument exhibit at the Sherman Hotel, Chicago, Ill. Richard Rimbach, 921 Ridge Ave., Pittsburgh, Pa., is exhibit manager.

**Sept 28-30—**

**Association of Iron & Steel Engineers.** Annual meeting to be held at Hotel William Penn, Pittsburgh. Pa. T. J. Ess, 1010 Empire Bldg., Pittsburgh, Pa. is managing director.

**Sept. 28-30—**

**National Electronics Conference.** Ninth annual conference to be held at the Sherman Hotel, Chicago, Ill. under the sponsorship of the American Institute of Electrical Engineers, the Institute of Radio Engineers, Illinois Institute of Technology, Northwestern University, and the University of Illinois, with participation by Purdue Uni-




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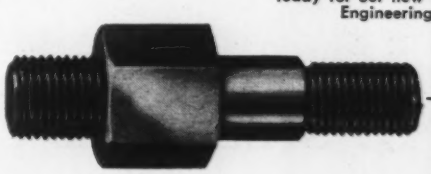

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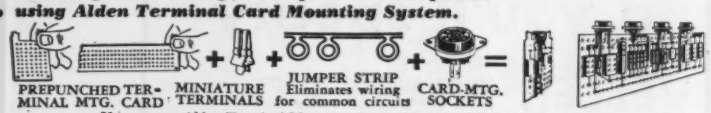
**1. *Unitize your circuitry in compact vertical planes using Alden Terminal Card Mounting System.***


PREPUNCHED TERMINAL MTG. CARD
MINIATURE TERMINALS
JUMPER STRIP Eliminates wiring for common circuits
CARD-MTG. SOCKETS
YOUR COMPLETED CIRCUITS FOR PLUG-IN PACKAGE OR CHASSIS

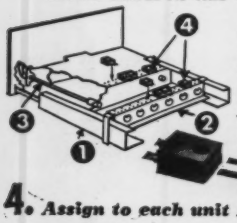
You can use Alden Terminal Mounting Card with Alden Miniature Terminals, Jumper Strip and Sockets staked to accommodate any circuitry — making complete units ready for housing. Components snap into unique Alden Terminals, are held ready for soldering.

**2. To mount this vertical circuitry, ALDEN PLUG-IN PACKAGES AND CHASSIS give tremendous variety with standard components**

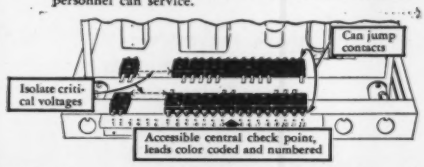
Alden components provide standard plug-in or slide-in housings—with spares, your circuits become units replaceable in 30 seconds.

**3. Give chassis easily traceable interconnects and 30-second replacement with ALDEN SERVE-A-UNIT KIT**

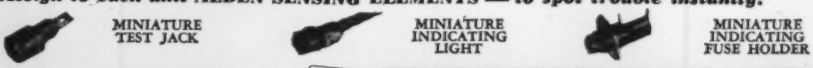
**IT'S AS SIMPLE AS THIS** Arrange Alden Side Rails (1) and Alden Lock Frame (2) to suit your chassis. Alden Serve-A-Unit Locks (3) mount in your chassis to engage pre-punched holes in Alden Lock Frame (2) to pilot, draw in, lock or eject. Arrange Alden Back Connectors (4) in orderly row on Alden Lock Frame. Mount mating Alden Back Connectors on your Chassis.




**GIVING YOU** 1) Chassis that plugs in, locks and ejects with half turn of the wrist. 2) leads so beautifully organized, accessible and identified that non-technical personnel can service.




**4. *Assign to each unit ALDEN SENSING ELEMENTS — to spot trouble instantly:***

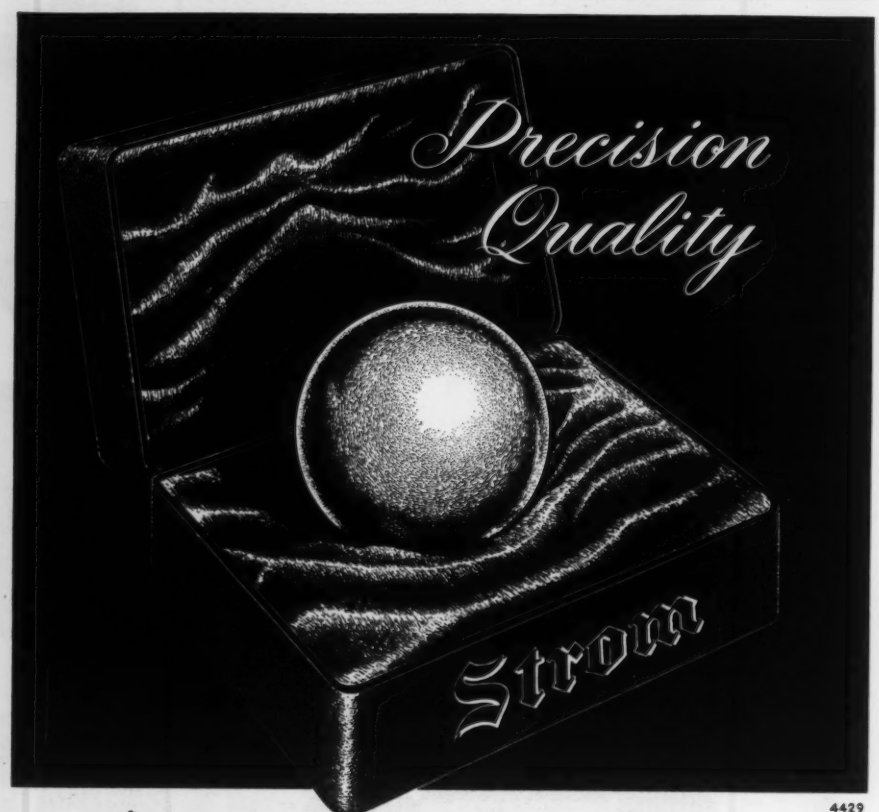



149 N. Main St., Brockton 64, Mass.

ALDEN PRODUCTS CO.

From Alden's Line of Ready-made Components for Unitized Plug-in Unit Construction.



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*Largest Independent and Exclusive Metal Ball Manufacturer*

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## Meetings and Expositions

versity and the University of Wisconsin. S. R. Collis, N. E. C. Publicity Committee, 208 West Washington St., Chicago 6, Ill., is chairman.

**Sept. 30-Oct. 2—**

**Porcelain Enamel Institute.** Twenty-second annual meeting to be held at the Greenbrier Hotel, White Sulphur Springs, W. Va. Additional information may be obtained from society headquarters, Dupont Circle Bldg., 1346 Connecticut Ave., Washington, D. C.

**Oct. 5-7—**

**American Society of Mechanical Engineers.** Fall meeting to be held at Hotel Sheraton, Rochester, N. Y. C. E. Davies, 29 West 39th St., New York 18, N. Y., is secretary.

**Oct. 8-9—**

**National Conference on Industrial Hydraulics.** Ninth annual meeting to be held at Hotel Sheraton, Chicago, Ill. J. G. Duba, Illinois Institute of Technology, Technology Center, Chicago 16, Ill., is secretary.

**Oct. 12-13—**

**First Conference on Mechanisms.** Two-day conference to be held at Purdue University, West Lafayette, Ind., under the joint sponsorship of the editors of MACHINE DESIGN and the faculty of the school of mechanical engineering at Purdue University. Additional information may be obtained from the Editor, MACHINE DESIGN, Penton Bldg., Cleveland 13. O.

**Oct. 19-23—**

**American Society for Metals.** National metal exposition and congress to be held at the Public Auditorium, Cleveland, O. W. H. Eisenman, 7301 Euclid Ave., Cleveland 3, O., is national secretary.

**Oct. 25-28—**

**American Gear Manufacturers Association.** Semiannual meeting to be held at the Edgewater Beach Hotel, Chicago, Ill. John C. Sears, 302 Empire Bldg., Pittsburgh 22, Pa., is executive secretary.

# New Machines

## Domestic

**Washer:** Has automatic timer which can be set to shut washer off at the end of a selected period of from 1 to 15 minutes or can be set to a "hold" position for operation beyond that period. Capacity of white porcelain washbasket is 8 lb of dry clothes. Lightweight black plastic agitator will not corrode or pit. Wringer rolls adjust automatically to varying garment thicknesses. Features quick-emptying impeller drain pump. *General Electric Co., Louisville, Ky.*

**Sink-Range-Refrigerator:** Combination appliance equipped with three gas or electric burners. Sink is adjacent to burners, and refrigerator occupies space directly below both units. Storage drawer is below refrigerator. Fiberglas insulation is used in sides, back, bottom, door and in space separating refrigerator and range sections. *General Air Conditioning Corp., Los Angeles, Calif.*

## Maintenance Equipment

**Floor Maintenance Machine:** Model "K" has 12½-in. diameter brush. Brush speed is 210 rpm. Power is transmitted from ⅓-hp heavy-duty vertical motor to brush through cog-tooth belt made of rubber and nylon, reinforced with multiple strands of steel cable embedded in the rubber. Motor is quiet running and does not require lubrication. Machine weighs 38 lb with brush. Attachments available to scrub, wax, polish, buff and sand all types of floors. *Hild Floor Machine Co., Chicago, Ill.*

**Steam Cleaner:** Electric Hydrosteam unit combines Speedylectric Steam-Jet and Sellers Injector Hydraulic Jet. Steam comes from a self-regulating steam generator. Solid jet of hot water and detergent under high discharge pressure and temperature removes grease deposits and soil encrustrations. Provides pin-point cleaning for delicate machine parts, motors and




KENTANIUM

LIVES with HEAT...

(UP TO 2200° F)

and likes it!

This new metal greatly widens the scope of engineering design where conditions of intermittent or continuous high temperatures in oxidizing atmosphere are combined with abrasion, and compressive or tensile loads.

WHAT is Kentanium?

Chiefly titanium carbide (and small percentages of other refractory metal carbides), with nickel "binder". Uses neither tungsten nor cobalt. Hardness: Up to 93 RA. Weight: ⅗ that of steel.

WHAT can it do?

Resist thermal shock, withstand oxidation and abrasion, retain great strength at high temperatures (1800°F and above).

WHERE is it in use?

Successful applications include: Valves, valve seats, reduction crucibles, anvils for spot welding, hot extrusion die inserts, bushings, thermocouple protection tubes, flame tubes, furnace tong tips, balls for hot hardness testing, nozzle vanes and blades for jet engines, and many others.

WHAT forms are made?

Tubes, rods, bars, flats by extrusion process. More complex parts by machining from pressed slugs before sintering; extremely accurate parts by grinding to required tolerance after furnace sintering.

HOW can you use it?

This remarkable new metal, available in many "grades" to meet specific combinations of imposed conditions, can best be adapted to your high temperature problem by cooperative effort. Our engineers will be glad to discuss how you can get best results from Kentanium.

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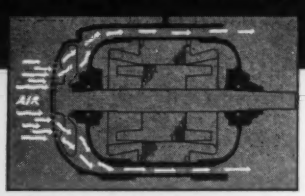
HEAT-RESISTANT, HIGH-STRENGTH, LIGHTWEIGHT CEMENTED TITANIUM CARBIDE

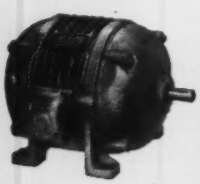
Let These
MOTORS
Do Your
DIRTY WORK

They're built to ignore dirt, dust and corrosive vapors




*SMITHway totally enclosed fan-cooled motor—a frame within a frame and both are cast iron. Efficient, high-capacity, double-locked fan forces air through self-cleaning ducts. Heat is dissipated—dirt, dust and corrosive vapors can't get into the sealed motor.*

CAST IRON construction is one of the many outstanding features which makes these motors superior under service conditions involving dirt, dust and corrosion. Cast iron frame, cast iron end bells—the complete enclosure is cast iron—all exposed parts are cast iron. Ideal for petroleum, chemical and other rugged industrial applications.
SMITHway totally enclosed fan-cooled motors are built to standard NEMA frames to meet the highest standards of electrical performance. TEFC motors are built in sizes from 5 to 125 HP. Parts and service available throughout U.S.A. Get complete information from nearest office or write today.



*SMITHway totally enclosed non-ventilated motor. Standard NEMA frames. Cast iron construction of all exposed parts keeps these motors, by the thousands, on the job regardless of dust, dirt and corrosive conditions. Available in ratings from 1 to 5 HP.*

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## New Machines

equipment that require protection from water and excess moisture. Steam lance can also be used for applying concentrated, undiluted solvents, detergents or stripping agents where needed to soften and loosen accumulations or coatings. Available in both stationary and portable models for operation on 220, 440 or 550-v three or two-phase, 60 or 25-cycle power supply. *Livingstone Engineering Co., Worcester, Mass.*

**Sewer Cleaner:** No. 420 "Sewer Master" clears obstructions 100 ft or more from sewer entrance; removes roots, grease, chips and other refuse. Cutting tools are attached to a coiled-spring snake which is remotely held and revolved by revolving chuck jaws. Motor reverses so that snake can be turned in either direction. *Oster Mfg. Co., Cleveland, O.*

### Materials Handling

**Pallet Truck:** Model SD combines single and double-faced load lift. Has ball bearing wheels and can be maneuvered in narrow aisles. Truck has 4-in. lift and can be furnished with hinged adaptors to allow use with skid platforms up to 12-in. underclearance. Overall width is 27 in. Forks are 9¼ in. wide, and the opening for the center runner of the pallet is 8½ in. wide. Available in 3000, 5000 and 10,000-lb capacities with either steel, rubber or plastic wheels. *Market Forge Co., Everett, Mass.*

**Loader:** Mounts on Case, Minneapolis-Moline, Sheppard and Oliver industrial wheel type tractors. Loads gondola cars, hoppers and trucks with bulk materials. Maximum lifting height, 16 ft; dumping height, 14½ ft. Load capacity is 6000 lb. Accessories include coal and snow bucket, loose material bucket and a crane hook tool. Bucket can be shaken while in dumping position. *Baker-Lull Corp., Minneapolis, Minn.*

**Fork Lift Trucks:** Models YC-40 and UC-30 have capacities of 4000 and 3000 lb, respectively, at 24-in. load centers. Powered by heavy-duty, water-cooled industrial

Precisioneered!

Universal Precisioneered Balls are, as the name suggests, engineered to precise tolerances . . . round all over, within ten-millionths of an inch. Extreme accuracy. Mirror finish. Quality-control throughout.

Where high speeds, silent operation, and minimal torsional resistance are musts, specify Universal Precisioneered Balls of chrome or stainless steels. Universal balls are also produced in all standard grades in chrome, stainless, bronze, solar aluminum and special materials . . . all 100% inspected, all individually gauged.

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Get absolutely
OIL-FREE
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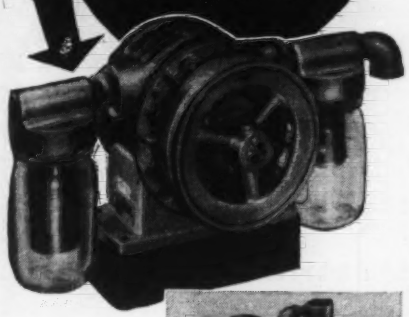
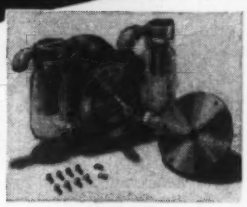
with GAST rotary
OIL-LESS
AIR PUMPS





Above — Oil-less Model 1550 — 8 to 10 C.F.M.
Right — Oil-less Model 3040, end plate removed. From 17 to 24 C.F.M.

**Three things about these pumps are outstanding:**

**FIRST** — They run *entirely without oil* in the pumping chamber. Four carbon vanes in rotor lubricate themselves — through thousands of hours of operation. Ball bearings are greased and sealed for life. You can *forget* oiling problems!

**SECOND** — They completely eliminate oil-mist in the air delivered. Used for *both* vacuum and pressure they *can't* contaminate your product or material with oil droplets.

**THIRD** — They're built with traditional Gast precision — for years of high performance and dependability.

**IF THESE QUALITIES** offer solutions to your original equipment problems, write Gast. Oil-less models from 10 to 20 inches vacuum — 3 to 10 lbs. pressure — 3.5 to 24 C.F.M.

See our CATALOG in SWEET'S FILE

**Write for new Data Sheet on Oil-less Pumps, showing 3 types and rating tables.**

*Original Equipment Manufacturers for Over 25 Years*

GAST ROTARY
AIR MOTORS (TO THREE H.P.) · COMPRESSORS (TO 30 LBS.) · VACUUM PUMPS (TO 28 INCHES)
GAST MANUFACTURING CORP., 107 Hinkley St., Benton Harbor, Mich.

## New Machines

engines and mounted on cushion type tires. Model YC-40 is 38 in. wide and 78½ in. long. Collapsed height is 82½ in. Will climb a 20 per cent grade loaded or empty. Model UC-30 is 74⅜ in. long and will climb a 24 per cent grade loaded or empty. Both trucks have sharp turning radius of 75 in. and 30 in. of free lift on standard 9-ft uprights. *Hyster Co., Portland, Ore.*

**Overhead Carrier:** Has cantilever arrangement that permits handling of loads beyond the end of the crane on which the carrier operates. Can move materials in areas between roof-supporting pillars and reach through doorways. Hoist reaches 2½ ft beyond end of crane. Capacity is 1500 lb. *Cleveland Tramrail Div., Cleveland Crane & Engineering Co., Wickliffe, O.*

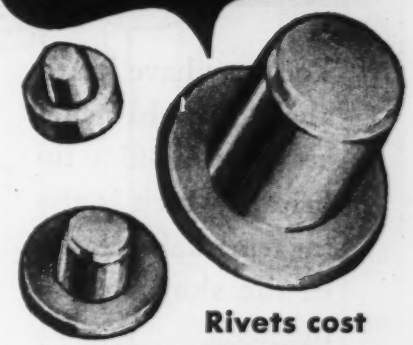
**Conveyor:** Redesigned LS aluminum belt conveyor is available in 10 and 16-in. widths and five lengths from 11 to 21 ft. Features free-rolling running gear and built-in jackscrew to raise and lower drive end of unit, permitting adjustment to desired belt pitch after head end of conveyor has been placed in position. Mounts on either two cushion-rubber demountable tire wheels, two pneumatic tire wheels or a dolly. Ruff-top belt elevates most materials at over 30-degree inclines. *Rapids-Standard Co., Grand Rapids, Mich.*

**Telescopic Fork Truck:** Capacity, 2000 lb. Elevated height of forks is 132 in.; collapsed height, 83¾ in. Base forks and elevating forks are 30 in. wide, 42 in. long. Truck has dual tandem load wheels; handles single-faced pallets and skid platforms. *Raymond Corp., Greene, N. Y.*

### Metalworking

**Small Rolling Mills:** Flat or grooved rolls on 3 and 4-in. mills produce shapes such as round, square, half-round and diamond or special shapes. Rolls are also supplied for such purposes as reducing or compacting small tubing sizes. Housings are cast of Meehanite type GM alloy to withstand

Economy and Practicality are by-words with Gibson CONTACT RIVETS



**Rivets cost less than other forms of electrical contacts and are easier to assemble . . .**

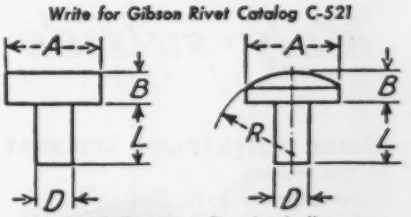
Gibson contact rivets are often the most appropriate and economical contacts for relays, switches, instruments and other applications involving small or moderate currents.

They are easy to install, are promptly supplied in standard or special sizes and shapes, and can be conveniently attached to springs or other supports at the Gibson plant — using supports furnished either by Gibson or the customer.

Moreover, Gibson contact rivets are readily available in fine silver, coin silver, or any electrical contact material capable of being cold-formed. Gibsiloy A-3, a case in point, combines all the advantages of silver with tougher wear resistance and reduced tendency to "freeze."

Let Gibson engineers recommend the best Gibson contact rivet for your needs. For rivet quotations, please submit dimensions (as shown below) and quantity desired.

*Write for Gibson Rivet Catalog C-521*




A = head diameter  D = shank diameter
B = head thickness  L = shank length
R = radius of face

CONTACT GIBSON FIRST

Gibsiloy ELECTRICAL CONTACTS
Manufactured by
GIBSON ELECTRIC COMPANY
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What do you know about the *Moly-sulfide* A LITTLE DOES A LOT LUBRICANT?

You may have heard about a highly successful solid-film lubricant which is giving remarkable results in the shop and in the field.

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MD-9 MS-3

## New Machines

stresses and shockloads. Heavy bronze bearings are enclosed within heavy-duty welded steel cabinet bases. The larger unit is available with roller bearings and can be water cooled. *Stanat Mfg. Co., Long Island City, N. Y.*

**Welder:** Lightweight shielded inert gas metal arc SWM-3 unit features arc voltage control. Electronic controls automatically vary welding wire feed rate as required by changing arc conditions. Makes butt, lap, fillet and corner welds in aluminum alloys, stainless steels, carbon steels, deoxidized copper, Everdur and aluminum-bronze in thicknesses from 16 gage. Uses welding wires of 1/32, 3/64, 1/16 and 3/32-in. diameter. Control unit can be permanently mounted or portable. *Linde Air Products Co., New York, N. Y.*

**Horizontal Boring Machine:** Features 6-in. diameter nitralloy spindle. Table will accommodate workpieces 12 ft long, 6 ft wide and 6 ft high. Indexing to less than 0.00025-in. is possible. Nonmetallic way eliminates metal-to-metal contact and prevents scoring. *G. A. Gray Co., Cincinnati, O.*

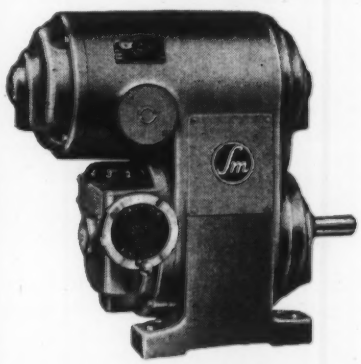
**End Finisher:** Has foot-controlled air cylinder. Work is fed to rotating cutters which are held in main spindle behind chuck jaws. When pointing is completed, chuck automatically returns the workpiece and unclamps. Automatic swing stock stop enables fast positioning of work in open chuck jaws. Adjustable stop screw controls forward travel and depth of cut. Machine reams, bores and faces tube and pipe ends; centerdrills bar stock and chamfers or forms rod ends. Positive clamping of work permits deburring, chamfering, and facing to be completed separately or simultaneously. Handles up to 2-in. diameter stock. Eight speeds range from 760 to 3920 rpm. Larger models for work up to 5-in. diameter available. *Pines Engineering Co. Inc., Aurora, Ill.*

**Bench Mill:** Performs such operations as making keyways, slotting, splitting, squaring at different angles, milling flat spots on small shafts, spline cutting and

50% Greater Concrete Strength Achieved

*The Yoder Company of Cleveland, Ohio, reports Sterling Speed-Trol, powering their revolutionary Continuous Concrete Mixer, gives the variable speed control necessary for continuous, accurate proportioning and mixing which made development of this machine possible. Compared to batch mixers, the Yoder Mixer increases concrete strength 50%, increases production at lower cost, and reduces equipment and maintenance costs over 50%.*

STERLING SPEED-TROL



GIVES YOU VARIABLE SPEED CONTROL NECESSARY FOR:

**Equipment adaptation to:** Sequence synchronization — operators' abilities — load variations due to differences in quantity, quality, weight, size, tension, hardness or shape of material to be processed, machined, conveyed, blended, mixed, etc.

**Process control of:** Temperature — viscosity — level — pressure — flow — etc.

**Time control of:** Baking — drying — heating — cooking — pasteurizing — soaking — chemical action — etc.

With Speed-Trol you get the maximum in production, plant efficiency, quality & profit.

**20-page illustrated catalog...** Sterling Speed-Trol, Slo-Speed, Klosd and Klosd-Tite Electric Power Drives. Write for catalog No. 1-A-424.

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# MACHINABILITY

of B&W mechanical tubing *You'll like it*

You'll find the machining characteristics of B&W Mechanical Tubing make it adaptable for turning out hollow cylindrical parts with any type of machine tool on mass production or jobbing basis. You can get this versatile tubing in grades, tempers, finishes and sizes to suit any combination of production conditions and product specifications. And no matter what analyses you need—carbon, alloy or stainless steels—to get the desired physical properties in your finished machined parts, B&W can supply them.

You'll find Mr. Tubes—your nearby B&W Tube Representative—a good man to consult when you need help in determining the best available mechanical tubing for your specific requirements.

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Precision Cap Screws

● Wherever shear, stress or vibration is encountered, **CHANDLER** cold forged metal fasteners assure perfect performance. Uniformly accurate, they speed assembly operations.

The quality and precision of **CHANDLER** cap screws can be measured by their wide use in major industries. **CHANDLER** fasteners are used by leading manufacturers of gasoline, jet and diesel engines designed for automobiles, aircraft and heavy equipment.

Whatever your requirements, specify **CHANDLER** precision cold forged cap screws.

- Grinding to Close Tolerances
- Drilled Heads or Shanks

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*Specialists in Thread-Rolling After Heat Treating*

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## New Machines

small screw slotting. Interchangeable pulleys make possible a range of speeds up to 7000 rpm. Powered with ⅓-hp, single-phase motor; operates on 110 v, 60-cycle ac. Set-up block measuring 3½ by 9 by ¾-in. high is machined with keyways on top and bottom at right angles. Single slide table with large dovetail ways and adjustable gibs permits 4 in. travel with plastic handle lever and has adjustable stop at both ends to limit travel. A ½ or 1-in. arbor and draw bar are used for end mill holders and arbors. Attachments for specific jobs available. Base is 11 by 18 in. *Viking Industries, Rockford, Ill.*

**Rolling Machine:** No. 490 series has maximum capacities of 1¼ to 3½ ips pipe or conduit; 1¾ to 4 in. OD steel tubing. Features fast, repeat positioning roll adjustment. When initial setting of bending roll is completed, reindexing is controlled by hydraulically actuated toggle mechanism. Pitch roll attachment on fixed drive roll provides means to obtain pitch desired in a coil. Initial bend may be started anywhere along length of material. Pipe or tube may be threaded on each end prior to rolling. Short radius bends can be made in rigid material in one pass through rolls. *Wallace Supplies Mfg. Co., Chicago, Ill.*

**Profile Mill:** Hydro Micro-Tel has tracer attachment. Automatic dynamic support leveling keeps table level automatically with removal of metal. Mill has automatic gib locking-devices. Pressure can be exerted on gibs, while in movement, to produce close tolerances. Hydraulic tracing is accurate to 0.001-in.; electronic tracing or profiling, to 0.0002-in. Spindle speeds selective, 0 to 2800 rpm; table and vertical travel selective, 0 to 200 in. per min. Selective spindle power feed and depth control to 0.0001-in. Working surfaces are 30 by 96 and 30 by 126 in. *DeWitt Lewis Co., Wayne, Mich.*

**Slide Feed:** For punch presses. Operates off press crankshaft, converting hand-fed presses to automatic operation. Maintains accurate feed on long or short runs without overthrows. Double feed

Concentration for Quality

Since 1919 Curtis has concentrated on the manufacture of only one line —

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As a result, Curtis research, production and quality control techniques have produced the widely accepted Curtis standards — and the world's best universal joints.

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**Availability** — 14 sizes always in stock; bored or unbored hubs. 6" hub diameter joints or special machining to specifications.

**Simplicity**—fewer parts, simpler construction.

**Government Tests** — complete equipment for government tests in our plant.

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*As near to you as your telephone*

A MANUFACTURER OF UNIVERSAL JOINTS SINCE 1919

# 26 types and 5,850 sizes —as near as your telephone

EVERY so often, a machinery maker comes to the Timken Company for help with a very special bearing application. Something, he's pretty sure, we've never encountered before.

Almost always, we're able to give him a pleasant surprise. In over 50 years of helping manufacturers with special bearing problems, all the while improving our designs, we've produced an astonishing variety of tapered roller bearings. So many sizes and shapes that the "new" bearing has usually already been designed and made by the Timken Company. So many that the "new" design problem has usually been already solved with the help of Timken Company engineers.

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Be sure that every bearing you use in the machines you buy or build is stamped with the trademark "Timken". The Timken Roller Bearing Company, Canton 6, Ohio. Canadian plant: St. Thomas, Ontario. Cable address: "TIMROSCO".

**TIMKEN** *TAPERED ROLLER BEARINGS*

TRADE-MARK REG. U. S. PAT. OFF.

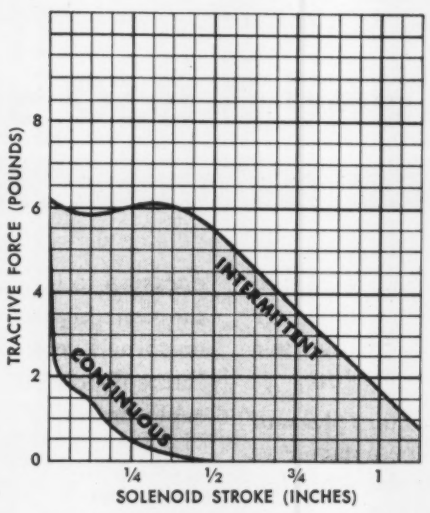
NOT JUST A BALL NOT JUST A ROLLER THE TIMKEN TAPERED ROLLER BEARING TAKES RADIAL AND THRUST LOADS OR ANY COMBINATION

Terminals are hermetically sealed by exclusive process developed for Cannon's widely acclaimed hermetically sealed electric connectors.
Insulation test: 1000v ac
The armature (plunger) and the anvil are high quality annealed Armco magnetic ingot iron.
Molded Nylon cap protects the terminals.
Molded "Silcan" cap protects the return spring and plunger end.
Silver brazed seals.

**TRUE**
*hermetic sealing*
*in this new*

**CANNON *dc* SOLENOID**

For pressurized or corrosion resistant service, Cannon's dc Solenoids offer positive hermetic sealing, sound construction, painstaking workmanship and highest quality materials. A vitreous insulating material is heat-fused to shell and contact terminals, creating a perfect seal. Other parts are silver brazed. The entire solenoid is then copper-nickel-chrome plated to insure complete coverage, high corrosion resistance and long, trouble-free service. Solenoid No. 19760, above, the first hermetically sealed product of this type, is built for continuous duty on 28v dc systems. Fitted with other coils, it renders intermittent duty as characterized by the chart at right. Cannon's hermetically sealed solenoid series reflects the same uncompromising attention to details of sound design, engineering and workmanship that has made the name "Cannon" synonymous with "quality" for more than 38 years. For complete information write for new Solenoid Bulletin DCS4-1953 showing 105 different assemblies.




Solenoids of the hermetically sealed 19760 series, through modification of the coil windings, can meet various characteristics and specific applications within the limits indicated above.

**CANNON ELECTRIC**
*Since 1915*

**CANNON ELECTRIC COMPANY, LOS ANGELES 31, CALIFORNIA**
Factories in Los Angeles, Toronto, New Haven. • Representatives in principal cities. Address inquiries to Cannon Electric Company, Dept. I-185, Los Angeles 31, California.


## New Machines

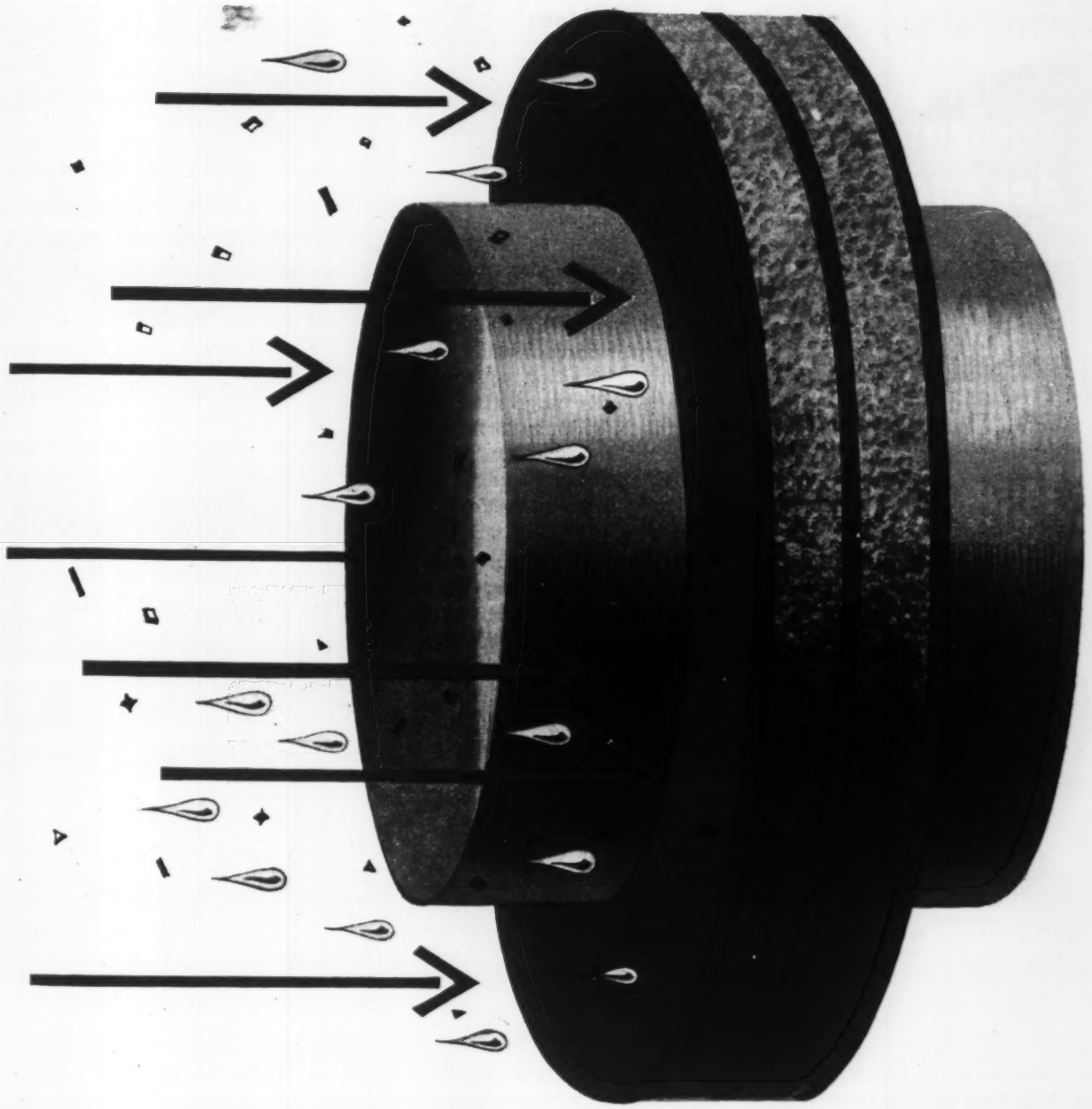
stops outside guide rods prevent interference with stock. Carbide-tipped gripper blade is adjustable vertically for hairline setting. It locks positively, allowing gripper to be engaged or disengaged without loss of adjustment. Available in various sizes to feed from front to back and back to front. *Cooper Weymouth Inc., Bridgeport, Conn.*

**Hydraulic Gap Press:** Model 220G, with 20-ton capacity, performs forming, drawing, bending, forcing, straightening, riveting, upsetting, piercing, crimping, and staking operations. Has motorized hydraulic system. Gap is 10 in.; platen size, 12 by 17 by 2½ in. Equipped with pressure gage and adapter. Tool shank is 2 in. ID, 2 in. deep. Floor space required, 22 by 36 in. Ram speed and stroke control made to specifications. *Studebaker Machine Co., Maywood, Ill.*

**Sheet Metal Fabricator:** Heavy-duty Model 10-C punches, notches and nibbles. Throat depth is 27 in. with back gage installed and 30½-in. without back gage. Punch assembly holder arm swings to the right for interchanging punches, reducing setup time. Punches and dies are automatically aligned by holder which permits punching holes up to 3½ in. in diameter. Work table is 56 by 37 in. Hydra-New-Matic head operates with little vibration and noise at 165 strokes per minute. Ram load is directly on frame, eliminating bending stress on drive shaft. *Wales-Strippit Corp., North Tonawanda, N. Y.*

**Lathe:** Simplex 20-in. model has hardened and ground spindle with American standard spindle nose. Lead screw is ground, has split nut and no backlash. Features Gap Bed which swings to 30 in. and is of reinforced, removable block type. Norton gear box is fitted with spline shafts and incorporates Shear-pin safety device, giving full range of American and metric standard threads. Available with 60 and 78 in. distance between centers. *Morey Machinery Co. Inc., New York, N. Y.*

**Gear Shaver:** Handles gears from 30 to 180 in. in diameter. Errors in tooth profile are reduced to



# "WORK CLOTHES" SOLVE TOUGH SEALING PROBLEMS

**American Felt Company**
TRADE MARK

GENERAL OFFICES: 22 GLENVILLE ROAD, GLENVILLE, CONN.

SALES OFFICES: New York Boston, Chicago, Detroit, Cleveland, Rochester, Philadelphia, St. Louis, Atlanta, Dallas, San Francisco, Los Angeles, Portland, Seattle, San Diego, Montreal — PLANTS: Glenville, Conn.; Franklin, Mass.; Newburgh, N. Y.; Detroit, Mich.; Westerly, R. I. — ENGINEERING AND RESEARCH LABORATORIES: Glenville, Conn.

Seal off your sealing worries with felt "work clothes!" Above is an OilFoil seal, used as protective "work clothes" in many machines. It consists of two layers of felt, bonded with three septums of Hycar, the synthetic rubber-like substance that is impervious to and unaffected by oils, greases and the hydrocarbons used in hydraulic systems. Such washers can have one, two, or three septums, to keep fluids in and seal out water, dust, dirt, gases, and retain pressures. If there is no enclosed lubricant, the felt can be impregnated with oil or grease, to provide long-time lubrication. OilFoil seals are supplied cut to exact dimensions, ready for assembly. For more information, write for Data Sheet No. 11, "Felt Seals, Their Design and Application."

a tolerance of 0.0002-in. and index or pitch errors are reduced to 0.0003-in. Saddle traverses in both directions and has stationary feed screws anchored at both ends. Headstock has two spindles, 40 in. between centers. Cutter head assembly includes two cutter slides with a journal alignment checker between them. Both are provided with power traverse and have precision, antifriction spindles. Machine weighs approximately 115 tons; is 24 ft long, 25 ft wide and, including large work gear, rises 18.5 ft above concrete foundation. *National Broach & Machine Co., Detroit, Mich.*

**Precision Grinder:** Model AP produces keen cutting edges and exact angles on carbide, stellite and high-speed steel cutting tools. Tools are rocked back and forth across entire wheel face, eliminating scoring and grooving of wheels. All front, side and top angles can be set precisely in both vertical and horizontal planes. Feed is controlled by a micrometer feed knob, graduated in thousandths of an inch. One side of grinder has an indexing table which remains fixed in set position without locking devices. Wheels can be vitrified or diamond. Available in bench and floor types for either wet or dry grinding. *Thomas Prosser & Son, New York, N. Y.*

**Straightener:** Sutton 2½L straightens steel and nonferrous flats and shapes at speeds from 100 to 1000 fpm. Has large roll shafts on close centers. Adjusting screws are overhung for greater stability when straightening larger sections. Will straighten squares from 5/16 to 1¾ in., hexagons from 5/16 to 2 in. and flats up to 3 by 5/8-in. Both vertical and horizontal straightening units adjust by means of pushbutton control of motor-driven screws. Roll adjustments are made manually by handwheels which are locked in position when machine is set up. Spring-loaded pinch rolls at entry ends provide positive feeding. *Sutton Engineering, Bellefonte, Pa.*

**Pointing Machine:** Built in four sizes for cold pointing tubes and bars of steel and nonferrous metals up to 6 in. in diameter. Four dies


You can depend on the rugged MARK-TIME "5400" Bell Time Switch

SPECIFICATIONS

UL approved for 20 ampere, 125 volt, 1 HP or 10 ampere, 250 volt operation, AC only. Timings available from 60 seconds to 5 hours. Normally supplied with center stud mounting. Other mountings available on request.

This Mark-Time switch is built to uphold the reputation of your product. Install it in your appliances, devices or machines, and give your customers a *double-purpose* time switch. "5400" turns OFF the circuit at the end of a pre-set time period . . . and gives a clear warning bell signal. Your customers will like that *double* service!

"5400" has a wide range of applications . . . is available with a wide variety of modern dials and knobs . . . can be supplied as an "ON" type of unit on special order.

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Round, solid, tubular. Rough cast or fully machined. Cored stock, all sizes (by ⅛" steps) from ½" minimum core to 26" O.D. 13" lengths or less. 6 grades of hardness.

Write for literature or send blueprints, conditions of operation and other data for quotations and recommendations as to alloys.

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are mounted in a fixed spindle head and therefore cannot revolve. A cage of annular rolls revolves around spindle head, blows being transmitted to dies through hammer blocks. Inner track of rolls is spindle head, outer track being fixed in flywheel. Taper wedges between dies and hammer blocks take up die wear. Amount of die opening is controlled by parallel cotters inserted in the side of hammer block and spindle head die slot. Stop, operated from rear, controls length of point. Steel tubes up to 2 in. diameter, nonferrous tubes up to 2½ in. diameter and aluminum tubes up to 3 in. diameter can be pointed manually. Power feeders are hydraulic and fitted with an oscillating hydraulic self-centering vise. *Etna Machine Co., Toledo, O.*

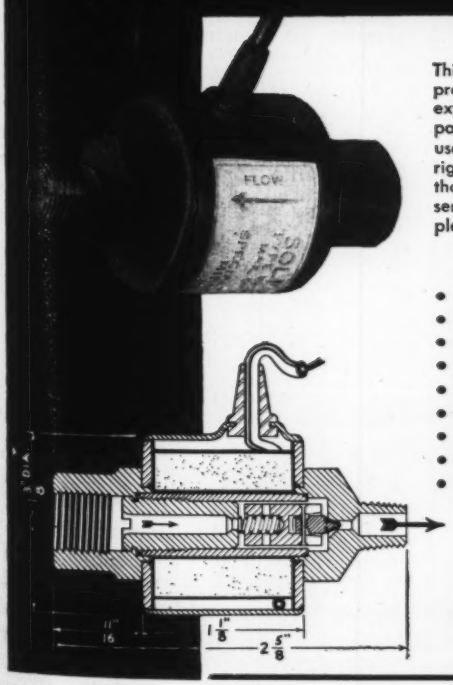
### Processing

**Recirculating Oven:** Model DRF-30 has 30-in. wide, 24-in. deep, 24-in. high chamber. Prime heat source is a bank of thin stripped heaters located in housing around insulated chamber. Operates at temperatures from 0 to 550 F. Outside air may be injected into the circulating system by means of an adjustable vent. Connected load is 6 kw, 220 v, 60 cycles, single phase. *Pereny Equipment Co., Columbus, O.*

**Washer:** Air-powered unit automatically cleans small parts. Oscillating turntable is submerged in cleaning solution and parts are placed in a perforated basket which rides on turntable. Speed varies from 0 to 240 oscillations per minute. Motor is operated by air pressures from 30 to 120 psi. Unit is 30 in. high; weighs 170 lb. *Kelite Products Inc., Los Angeles, Calif.*

**Painting Machine:** Automatic, single-spindle unit can be used in most standard spray exhaust booths. Dial regulates spindle speed from 100 to 400 rpm; another controls duration of spray gun operation. Spindle and guns are activated by a foot pedal but stop automatically as predetermined by dial settings. Spray guns can be mounted on each of four corners of machine. *Conforming Matrix Corp., Toledo, O.*


SOLENOID VALVES
WITH ADVANTAGES PLUS




This valve of unique and practical design has proved itself in the past seven years to have extreme endurance and reliability. Important parts are stainless steel and no gaskets are used whatsoever. All parts silver brazed for rigidity. Look no further for a solenoid valve that will give years of trouble free, efficient service. Write today for full information. Samples available for inspection and test.

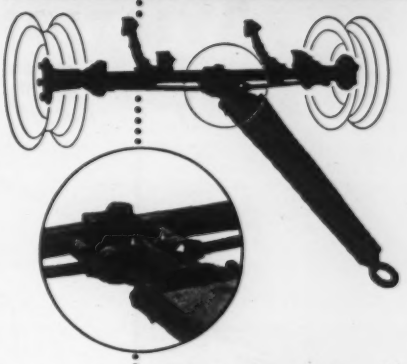
IMPORTANT FEATURES:

- All brazed construction
- No mounting brackets
- Weight 5 ounces
- Positive seal at any pressure
- Operates in any position
- Operates up to 1000 cycles per minute
- Power consumption 1 to 3 watts
- Pressure up to 200 p.s.i.
- Straight through flow

*Specialty*
PRODUCTS CO., INC.
3725 Monitor Ave.
Minneapolis 16, Minn.



UNITED CARAVAN AXLES



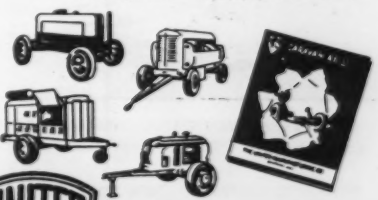
feature
AUTOMOTIVE STEERING

Only CARAVAN axles with automotive steering assure dependable roadability on both highway and rough ground. For positive trail at high speeds, these job-engineered assemblies feature controlled camber, tow-in and caster.

Stability for the heaviest loads is provided by massive center steering arm, extra-heavy center arm stop blocks and heavy duty steering knuckle. Wide inside wheel turning angle assures maximum maneuverability and eliminates jack-knifing.

CARAVAN units are available in a variety of types and sizes in both 2 and 4-wheel assemblies for portable equipment weighing from 500 to 14,000 lbs. They are recommended for use with military and industrial as well as field service and construction equipment. 1125-UM

*Write today for the new Bulletin No. 53 for further information.*



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914 INTERSTATE ST. • BEDFORD, OHIO

**LORD** Mounts have become a vital part of the Automotive and Aviation Industries during the past quarter century. The vast reservoir of experience as a prime supplier is of great practical value to design engineers of today. Thousands of Lord Mounts protect the most sensitive instruments and the most rugged of component parts from shock and vibration.

Shown here are a few typical Lord applications used in wide diversity in the industry. We welcome the opportunity to help you with your shock and vibration problems.

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**DAYTON 2, OHIO** 410 West First Street
**DETROIT 2, MICHIGAN** 311 Curtis Building
**NEW YORK 16, NEW YORK** 280 Madison Avenue
**CHICAGO 11, ILLINOIS** 520 N. Michigan Ave.
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**LORD MANUFACTURING COMPANY • ERIE, PA.**

LORD BONDED RUBBER — *Headquarters for* **VIBRATION CONTROL**


*Advertisement*

## Lord Bonded-Rubber Products Set Standard In Vibration and Shock Control For Over Twenty-Five Years

In the field of technical analysis and engineering to "design out" destructive factors set up in the machines of industry by vibration and shock, Lord Manufacturing Company continues to pioneer and set the pace for precision made vibration control mountings and bonded-rubber parts.

Years of experience in mounting aircraft engines and airframe components enable Lord Engineers to help industrial equipment designers in obtaining smoother operation, longer service life and increased safety in their machines.

Lord Engineers draw from some 27,000 basic designs and their variations to solve many vibration and shock problems referred to them by machine designers. Add to this the continuous research engineering available from the company's complete laboratories, and it becomes a matter of near impossibility to present a vibration problem which cannot find soluton in the Lord Organization. The scope of Lord Design and Precision Manufacture covers Vibration Control Mountings for aircraft engines and components in both the internal combustion and jet field, delicately balanced and precisely assembled units of accounting machines, electronic equipment, instrument panel mountings, shipping case mountings for the protection of sensitive machines in transit.

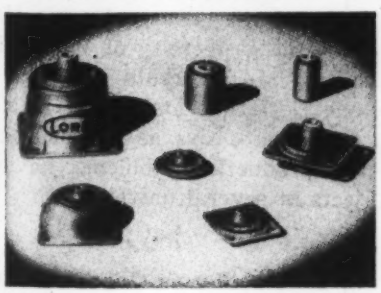
Designers of home appliances use Lord bonded-rubber parts for fan-hubs, flexible couplings and special components for washing machines, room air conditioners, mixing and juicing devices. Lord Flexible Couplings are used in the mechanism which operates motorcar windows and convertible tops. The turbine engine for heavy duty motor truck transport, a recent development of the Boeing Airplane Company, is connected to the power transmission by a special Lord Flexible Coupling and the engine itself is supported on Lord Mounts. Lord Engineering and Precision Manufacturing facilities are available to business and industry wherever Vibration and Shock Isolation problems require a precise, accurate and inexpensive solution.

*Advertisement*

## Lord Vibration Control Mountings . . . The Most Effective Protection For Electronic Equipment

In the rapidly advancing field of electronics, the control of destructive vibration and isolation of damaging shock are prime factors in the consideration of design engineers. Lord, Headquarters for Vibration Control, is constantly working with electronics engineers to improve the methods for protecting sensitive mechanisms.

For instance, Varo Static Converters which change alternating to direct current for aircraft with less than 1% voltage ripple are protected against shock and vibration by Lord Mountings. High fidelity Audio frequency electronic equipment such as Collins Radio Company manufactures is protected from vibration and shock through the use of Lord Mountings. The 212A-1 Broadcast Station Speech Input Console by Collins requires 28 Lord square Plate Form Mountings to protect each amplifier stage individually. This prevents mechanical interaction between stages and lessens acoustical feed-back effects.



Again the Agnew Spark Plug Welder by Agnew Electric Company uses Lord Mountings to support the electronic weld timers to prolong the useful service life of Mercury Vapor Tubes. .

Lord Mountings, which you see illustrated in the accompanying advertisement, are used in a wide diversity of applications to protect electronic equipment and sensitive instruments. Business machines and such sensitive mechanisms, the accuracy of which must be perfect, are improved in operation and protected from damaging vibration and shock by Lord Mountings.

The Lord Manufacturing Company, Erie, Pa., offers a vast reservoir of recorded experience in the solution of vibration and shock problems. Your request for help on your own problem is welcomed.

VIBRATION and shock are natural enemies of electronic equipment and precision instruments . . . To control the damage which these enemies can do, Lord Vibration Control Mountings and Bonded Rubber Parts are used to very profitable advantage. More than a quarter century's experience in dealing with vibration and shock is yours when you take advantage of Lord engineering assistance. The result of such consultation is full protection for electronic units and sensitive instruments by correctly designed and precisely manufactured Lord Mountings and Bonded-Rubber parts.

**SAE National Aeronautic Meeting, Hotel Statler—Booth 21**
**Los Angeles, California, Sept. 29—Oct. 3, 1953**

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**LORD MANUFACTURING COMPANY • ERIE, PA.**

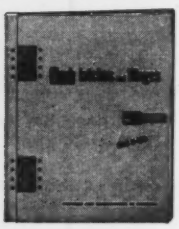
LORD BONDED RUBBER

*Headquarters for*
**VIBRATION CONTROL**

**Hartwell Flush Latches**

**available for over 300 COMBINATIONS of door and frame thicknesses**

Hartwell Trigger-action Flush Latches are produced in over 300 stock combinations of bolt and trigger offsets. We can supply a latch for any door of any thickness to be latched in a frame of any thickness to your specifications. No altering of panels and frames is necessary when Hartwell Flush Latches are installed. Offsets of bolt and trigger are stamped on each part for rapid and accurate selection of the correct latch for each installation.
All Hartwell Flush Latches and Hinges are the result of over a decade of continuous specialized design and manufacture.



*Write for new Flush Latch and Hinge Catalog.*

**HARTWELL COMPANY**
9035 VENICE BOULEVARD,
LOS ANGELES 34, CALIFORNIA

# MEN OF MACHINES

Theodore F. Eserkaln

**Theodore F. Eserkaln** has been appointed chief engineer of the Kempsmith Machine Co., Milwaukee. He will direct an accelerated program of engineering development. Mr. Eserkaln has long been associated with the design of milling machines. For many years he was assistant chief engineer of the Kearney and Trecker Corp., where he supervised the development of equipment for high-speed carbide milling. More recently he served as director of engineering at the George Gorton Machine Co. A graduate of the University of Wisconsin in mechanical engineering, Mr. Eserkaln has been a member of the Machine Design Committee of ASME for some years and has been active as a consultant on machine design and production problems, having lectured on such subjects at several universities.

♦

The Reliable Spring & Wire Forms Co., Cleveland, has appointed **John B. Malloy** to the position of chief engineer. Since 1929 Mr. Malloy has been associated with the Bethlehem Steel Corp., Republic Steel Corp., Wheeling Steel Co. and the Cuyahoga Spring Co.

♦

**Frank S. Schindler** has been appointed assistant chief engineer of Fluid Controls Inc., Mentor, O. He has served in engineering and supervisory positions with Brainard Steel Co., Flexonics Corp. and Spencer Mfg. Co. In his new position, Mr. Schindler will coordinate the functions of all company departments.

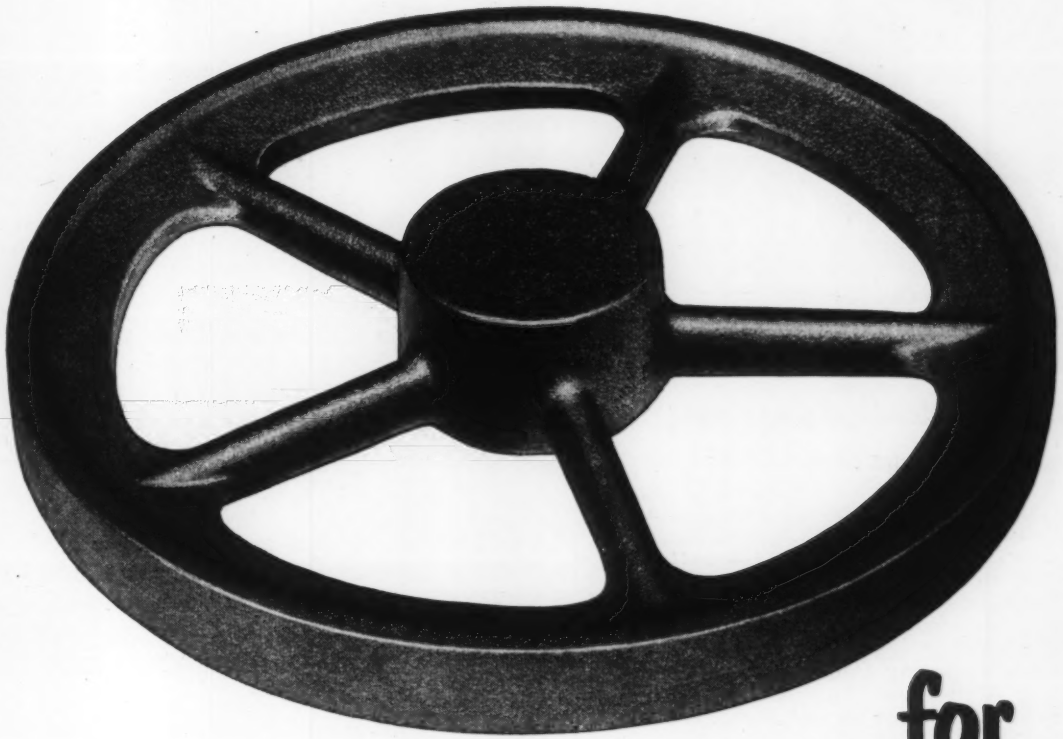
♦

New manager of application engineering at the Gearing Div. of Westinghouse Electric Corp., Pittsburgh, **A. Morton Cooper** succeeds **G. H. McBride,** who has been appointed assistant manager of the company's Switchgear Div. at East Pittsburgh.

♦

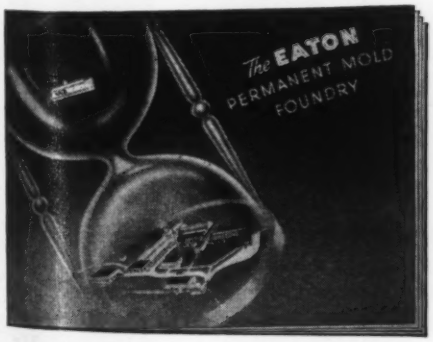
High Vacuum Equipment Corp., Hingham, Mass., has appointed **Glen Mellen** to the position of chief

# Eaton Permanent Mold Gray Iron Castings—



for

# V-BELT PULLEYS




Send for your free copy of the 32-page illustrated booklet: "The Eaton Permanent Mold Foundry." It tells the story of Permanent Mold Castings and takes you on a picture-tour of the Eaton Foundry at Vassar, Michigan.

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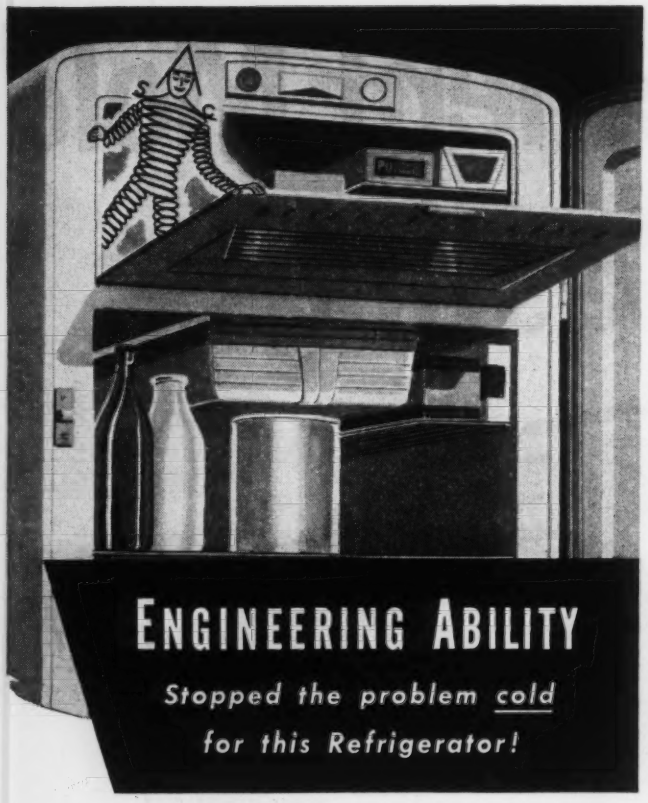
**PRODUCTS:** Sodium Cooled, Poppet, and Free Valves • Tappets • Hydraulic Valve Lifters • Valve Seat Inserts • Jet Engine Parts • Rotor Pumps • Motor Truck Axles • Permanent Mold Gray Iron Castings • Heater-Defroster Units • Snap Rings Springtites • Spring Washers • Cold Drawn Steel • Stampings • Leaf and Coil Springs • Dynamatic Drives, Brakes, Dynamometers




**. . . with Springs by Automatic Spring Coiling Co.**

**The need was very specific—**

"Give us a spring," this refrigerator manufacturer requested, "that can THINK . . . so to speak. We have an evaporator door to the cold chest compartment that must respond to the touch of a finger, swing open to a certain angle, and stop there. It should also be possible to close the door with a nudge of a food-burdened housewife's elbow."

So . . . Automatic Spring Coiling Co. was called in and *Engineering Ability* came through!

The answer . . . calculated by our engineers was to design a spring with precisely the right *build-up,* with just the right combination of spring and wire diameter. In this way, not only would the spring do the required job—metering out its energy at the right rate—but also tolerances would be such that production could be handled with facility on our high speed equipment.

Put Automatic Spring Coiling Co. to work on *your* spring problem. See how members of our entire organization — consultants, designers, sample-makers, inspectors—swing into operation and *click.* Working as a well-integrated team with strict adherence to Quality Control we pledge ourselves to bring you the finest, most dependable springs to insure the successful and efficient performance of your product.

*Our veteran consulting engineers are ready to survey your requirements without obligation. Please write.*

**AUTOMATIC SPRING COILING CO.**
**4043 West Thorndale Avenue**
**CHICAGO 30, ILLINOIS**

## *Men of Machines*

development engineer. He was project engineer at the MIT Lincoln Laboratories and previously served as special project engineer on balloon instrumentation for General Mills, as research engineer on electromagnetic devices and digital computers for Control Engineering Corp., and, from 1943-1950, as a member of the research staff of National Research Corp. From 1948 to 1950 he was director of the National Research applied physics department.

♦

**James J. Black** has been named vice president of engineering of Trailmobile Inc., Cincinnati. Mr. Black joined the company in 1931 and the next year became chief engineer for the Highland Body Co., a Trailmobile subsidiary. In 1934 he was named chief engineer for both companies.

♦

Election of **W. Walter Watts** to vice president in charge of technical products and **Theodore A. Smith** to vice president in charge of the engineering products department has been announced by the RCA Victor Div. of Radio Corp. of America, New York. Previously vice president in charge of the engineering products department, Mr. Watts will supervise the activities of both that department and the tube department of the Victor Div. Mr. Smith was previously assistant manager of the engineering products department.

♦

**Fay Carlson** has been named manager of the quality control department of the Warner Electric Brake & Clutch Co., Beloit, Wis. Mr. Carlson was formerly director of quality control at Sunstrand Machine Tool Co.

♦

Formerly staff engineer, **John N. Wolfram** has been named to the new post of administrative engineer at the Parker Appliance Co., Cleveland.

♦

**John F. Haller** was recently elected vice president in charge of engineering of Allied Products Corp., Detroit. He will continue to direct the development work of Michigan Powdered Metal Products Co. Inc., a wholly-owned Allied subsidiary.

♦

Associated with the Nichols Wire & Aluminum Co., Davenport, Iowa, for 30 years, **M. J. Fey** has been promoted to the position of executive engineer. His new duties will include supervision of development and design.

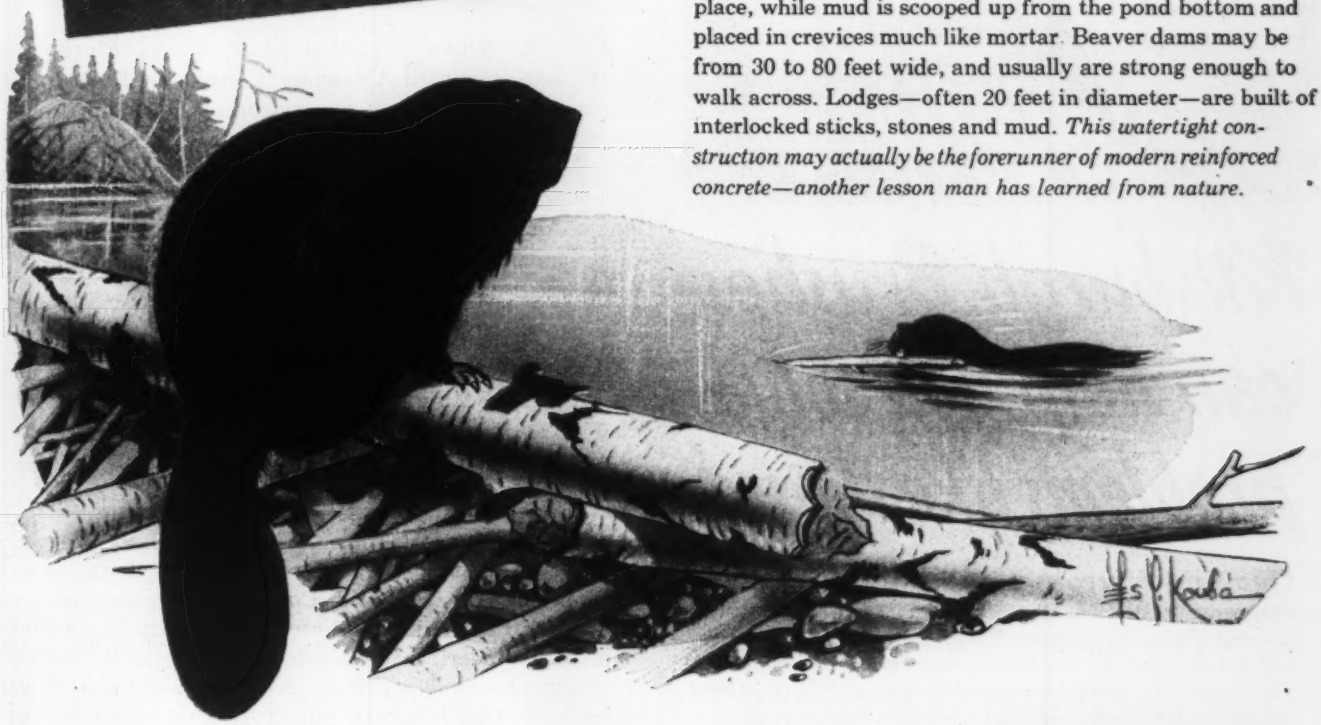
♦

Sylvania Electric Products Inc., New York, has appointed **E. Finley Carter** technical director and **Howard L. Richardson** in charge of engineering operations. Mr. Carter has been a vice president since 1945, and Mr. Richardson, since 1951. In his new capacity, Mr. Carter will furnish technical counsel to the company's management and engineering groups and will handle broad technical relations with industry, universities, the armed services and other organizations. Mr. Rich-

# LESSONS IN HYDRAULICS

## The Beaver

The beaver's building skill captures the imagination of engineers and naturalists alike. This industrious animal is undoubtedly the "woodland's greatest hydraulic engineer" In constructing dams and lodges, he cuts down small trees, dragging them into the water. Stripped of bark, these sticks and poles are shoved endwise into the dam or lodge structure. Stones are pushed or carried to the site and wedged into place, while mud is scooped up from the pond bottom and placed in crevices much like mortar. Beaver dams may be from 30 to 80 feet wide, and usually are strong enough to walk across. Lodges—often 20 feet in diameter—are built of interlocked sticks, stones and mud. *This watertight construction may actually be the forerunner of modern reinforced concrete—another lesson man has learned from nature.*



# WOODLAND'S GREATEST HYDRAULIC ENGINEER

Many products have design features requiring a hydraulic seal with special properties in addition to close tolerances and extreme uniformity. If yours is such a product, you'll want to know more about *injection molded* Minnesota O-Rings. Available in numerous compounds of natural or synthetic rubber, Minnesota O-Rings have great tensile strength, extreme capacity for pressure, and high resistance to compression set, abrasion, and oil swelling. Check these examples of successful installations in air, gas, and hydraulic systems: dispensing mechanisms . . . hydraulic rams and valves . . . air cylinders . . . remote control mechanisms . . . spraying equipment . . . gasoline and steam engines . . . and water pumps. Minnesota O-Rings are the choice of industries leading engineers and product designers. For prompt analysis and quotation on your requirements, send us your blue prints or specifications.

INJECTION MOLDED MINNESOTA O-RINGS

Minnesota Rubber's exclusive injection molding process produces O-Rings and other small rubber parts to meet extreme uniformity and tolerance requirements . . . and at low average prices. *Send for bulletin on injection molded Minnesota O-Rings.*

**MINNESOTA RUBBER & GASKET CO.**

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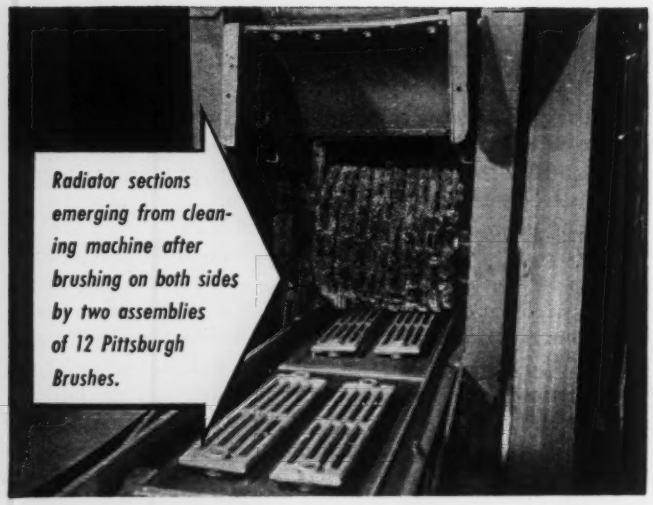
Radiator sections emerging from cleaning machine after brushing on both sides by two assemblies of 12 Pittsburgh Brushes.

# Pittsburgh Brushes can help you solve problems like these!

***Cleaning Narrow Spaces***—National Radiator Company, Johnstown, Pa., cleans 30,000 radiator sections a week! To insure a perfect final finish, even the narrowest spaces must be absolutely clean prior to assembly. Pittsburgh engineers were asked to design a brush that would reach these spaces and would fit National's existing machine. Successful? National reports: "Pittsburgh Brushes do a better job of cleaning and are more economical."

***Preparing Chills***—At Continental Foundry & Machine Co., East Chicago, Indiana, chills used to cast iron rolls must be cleaned of the oxidized metal remaining from previous usage, as well as dirt and grease accumulated in storage. After experimenting with other brushes, Continental chose Pittsburgh because they "do the job better and stand up longer than any previously used."

***Improving Original Equipment***—The Sommer and Maca Glass Machinery Co., Chicago, Illinois, uses Pittsburgh Brushes in the automatic washing machines they manufacture. Brushes formerly used simply didn't have the over-all density pattern needed. Pittsburgh engineers studied the problem and designed a brush which Sommer and Maca approved "because of (its) denser bristle pattern and lower cost."

**WRITE TODAY FOR FREE BOOKLET!**

Write today for a free copy of our booklet that shows, through actual case histories, how Pittsburgh cuts brushing costs. Address: PITTSBURGH PLATE GLASS COMPANY, *Brush Div.*, Dept. W-5, 3221 Frederick Ave., Baltimore 29, Maryland.

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## Men of Machines

ardson assumes the operating responsibilities previously held by Mr. Carter as vice president in charge of engineering.

♦

**Warner Livingston** was recently named assistant general manager of the Stratos Div. of the Fairchild Engine and Airplane Corp. in Bay Shore, L. I., N. Y.

♦

Trans-American Precision Gear Corp., Flushing, N. Y., has appointed **Alexander Yorinks** as director of engineering. Formerly supervisor of mechanical engineering at Airborne Instruments Laboratory Inc., Mr. Yorinks has also been affiliated with Reeves Instruments Corp., Sperry Gyroscope Corp., Bendix Aviation Corp. and E. W. Bliss Co. in the development of precision gears and instrumentation in the electromechanical field.

♦

**Harold W. Pope,** formerly chief engineer of Convair's Guided Missile Div. in San Diego and Pomona, Calif., has been elected an associate of Sanders Associates Inc., Nashua, N. H. He will direct guided missile and aeromechanical activities.

♦

Newly appointed manager of product design and engineering for Polaroid Corp., Cambridge, Mass., **Murry N. Fairbank** will direct the activities concerning the engineering and development of the firm's new photographic and optical products, including new models of the Polaroid picture-in-a-minute camera, special adaptations of the Land 60-second process to military devices, and a variety of optical products. Mr. Fairbank was associated with Bendix Aviation Corp. before joining the Polaroid research department in 1939.

♦

Formerly associated with the Atomic Energy Commission, **Arthur V. Peterson** has joined the staff of the vice president in charge of engineering of American Machine & Foundry Co., New York. He will concentrate on expansion of the company's activities in the atomic energy field.

♦

**Robert J. Stahl,** formerly chief engineer of Color Television Inc., has joined Dalmo Victor Co., San Carlos, Calif., as consulting engineer.

♦

Specializing in special machine design and providing consulting services to the paper, paper converting and printing industries, **John B. Kohler** has opened offices at 218 Woodstock St., Crystal Lake, Ill.

♦

Acme Steel Co., Chicago, has announced the appointment of **Stephen Rasul** as manager of design and production engineering for the company's plant in Riverdale, Ill. **Thomas Fullerton** has been named chief engineer in charge of all machine design and production engineering activities.

Advertisement

## Special Treatment Withstands Condensation of Moisture On Motor Windings at -38°

Industrial trucks built by Crescent Truck Company, Lebanon, Pennsylvania, for use in the plant of Polar Cold Storage Company, are specially engineered for the application.

Trucks are built with an extremely short turning radius to permit ready maneuvering in the narrow aisles necessary to conserve space in a cold storage warehouse. Special treatment of the windings on the drive and pump motors is also necessary to withstand condensation of moisture with the trucks entering and leaving the 38 degree-below-zero refrigerated areas.

Crescent lift trucks used in this cold storage warehouse are powered by Star-Kimble traction motors with windings treated to prevent condensation of moisture.

Drive and pump motors for this severe service were engineered and built by Star-Kimble. Motors are of the ET type, designed for 30-volt storage battery operation, and use Class B insulation to provide high capacity and compactness.

The Class B insulation is treated with a varnish formulated to withstand condensation of moisture on the windings. The Star-Kimble motors on these Crescent trucks have been in service for periods as long as five years (9 hours a day), under severe loading conditions and extremes of temperature, with little or no maintenance.

Information on Type ET d-c traction and pump motors for industrial truck service is available from Star-Kimble Motor Division of Miehle Printing Press and Mfg. Co., 201 Bloomfield Avenue, Bloomfield, New Jersey.

## WITH STAR-KIMBLE BRAKEMOTORS

**Stopping** of a Star-Kimble Brakemotor is split-second in action, precisely timed by simple adjustments. Quiet, too — no lining screech. Low lining pressure, evenly distributed, assures long brake life. Brake is self-adjusting to compensate for lining wear — ruggedly built to withstand shock and vibration.

Braking force is spring applied, magnetically released. No linkages to cause lost motion or friction.

**Starting** of a Star-Kimble Brakemotor is smooth and free from drag. Small magnetic air gap assures quick brake release without high inrush current.

And Star-Kimble Brakemotors *maintain* this fast, smooth stop-start operation through millions of cycles with little or no maintenance attention. Brake and motor are *designed* together to work together as a single compact unit. One manufacturer, one responsibility — backed by years of experience. For details on construction, motor ratings and braking torques, write for Bulletin B-501-A.

**Standard and special motors of all types, 1 to 600 hp; Marine motors ½ to 600 hp; generators and motor-generator sets, 1 to 500 kw.**

**STAR-KIMBLE**

MOTOR DIVISION OF

MIEHLE PRINTING PRESS AND MFG. CO.

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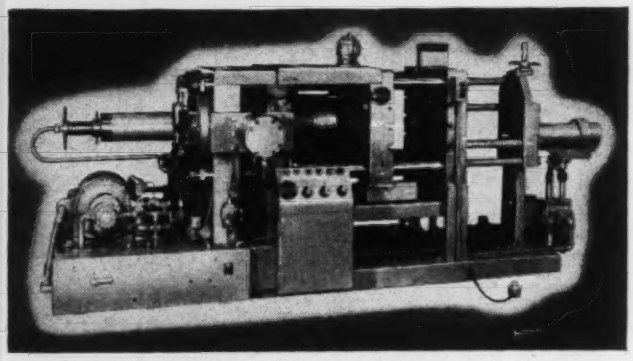
# HOW PALMETTO G-T RING "showed" CUYAHOGA INDUSTRIES its superiority in PACKING PERFORMANCE

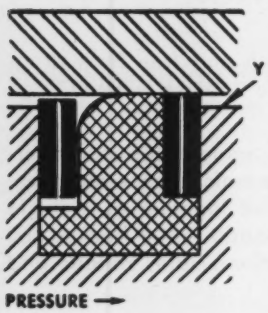


## This Ohio firm was "from Missouri" where packing was concerned

At Cuyahoga Industries in Cleveland, Ohio, the Palmetto G-T Ring and a conventional packing were matched for performance in a Cuyahoga-made 600 ton Wedgelock Die Casting Machine. Results: The conventional packing with leather back-up rings extruded and had to be replaced within three months. Palmetto G-T Ring performed satisfactorily without replacement for over a year! When it's getting too tough for other packings, it's "just right" for G-T Ring.

**THE KEY TO LONG SERVICE UNDER PRESSURE IS NON-EXTRUSION . . . THE KEY TO NON-EXTRUSION IS THE**

**PALMETTO® G-T RING**




As pressure is applied, conventional packings soon extrude into clearance space Y, then fail. Not so the G-T Ring! Because of its design consisting of a resilient sealing ring in a T-Section supported on each side by two non-extrusion rings, it cannot extrude. As pressure is applied to the G-T Ring, the resilient material flows under the non-extrusion rings, urging them against the cylinder wall and blocking the path of extrusion.

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Write for your complimentary copy of the new Greene, Tweed manual. This helpful 32-page handbook for the design engineer covers Palmetto G-T Packings in detail—as well as other noteworthy Palmetto Molded Packings.

*packing more performance into every application* — PALMETTO Packings

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# THE ENGINEER'S Library

## Recent Books

**Design of Machine Elements.** *By M. F. Spotts, professor of mechanical engineering, Northwestern University; 520 pages, 6 by 9 inches, clothbound; published by Prentice-Hall Inc., New York; available from* MACHINE DESIGN, $9.65 *postpaid.*

A second edition, this book deals with the fundamental principles required to design the separate elements which compose machines. Many illustrations are dispersed throughout the book along with a large number of problems and solved examples. Extensive bibliographies are included at the end of chapters. Text material covers stress and strain relationships, shafting, springs, screws, belts, clutches, brakes, welded and riveted connections, lubrication, ball and roller bearings, gears and gearing, miscellaneous machine elements, dimensioning and details, and engineering materials.

♦

**The Induction Motor.** *By Herbert Vickers, consulting engineer, London; 543 pages, 6 by 9 inches, clothbound; published by Pitman Publishing Corp., New York; available from* MACHINE DESIGN, $15.00 *postpaid.*

The first edition of *The Induction Motor* was published in 1924. This second edition has been revised to incorporate modern methods and practices of ac machines including fractional horsepower motors. Emphasis has been placed on design and design principles. Much additional material has been introduced in this edition concerning single-phase machines, selsyns, the three-phase series and shunt commutator motors, a new theory of the single-phase motor, and the application of symmetrical components to conditions of unbalance.

♦

**Elements of Internal-Combustion Engines.** *By A. R. Rogowski, associate profesor of mechanical engineering, Massachusetts Institute of Technology; 244 pages, 6 by 9 inches, clothbound; published by McGraw-Hill Book Co. Inc., New York; available from* MACHINE DESIGN, $5.50 *postpaid.*

Basic theory is presented in this text for engineers desiring a knowledge of the factors involved in safe and efficient operation of various types of internal-combustion engines. Following the introduction which covers nomenclature and engine types, a discussion of physical principles, air cycles, fuel-air cycles, and engine cycles is given. Friction, detona-

DOW

# MAGNESIUM FINDS INCREASING FAVOR AS DIE CASTING METAL

## Advantages of light weight, easy machinability and competitive cost make Magnesium preferable for many types of die castings

Many manufacturers are taking a new look at magnesium as a die casting metal. In today's competitive markets, magnesium offers advantages that can't be overlooked.

Take light weight. Magnesium is the world's lightest structural metal. Where weight is a competitive factor, magnesium is the metal to use. A manufacturer of portable electronic dictation equipment found that nineteen castings in zinc weighed 13 pounds, 6½ ounces; and *in magnesium, 3 pounds, 10 ounces.* That's real weight saving!

Magnesium is well known as the easiest of all metals to machine. This in itself promotes economy. As an example, the manufacturer of a lubricating machine found that the cost of machining an oil reservoir cast in grey iron was $2.05 while machining the same part cast in magnesium cost only 80¢.

Cost-wise, magnesium is better than competitive in numerous applications. One large automotive manufacturer (an industry where cost is figured on a fractional basis) has found magnesium die castings to be the lowest in cost of any metal in a score of applications. Moreover, magnesium's long-time record of price stability is also an important factor.

Now's a good time to take a close look at magnesium. For the competitive markets ahead, magnesium can offer you many advantages. Your nearest Dow office can give you up-to-the-minute information. Or write THE DOW CHEMICAL COMPANY, Magnesium Department, Midland, Michigan.

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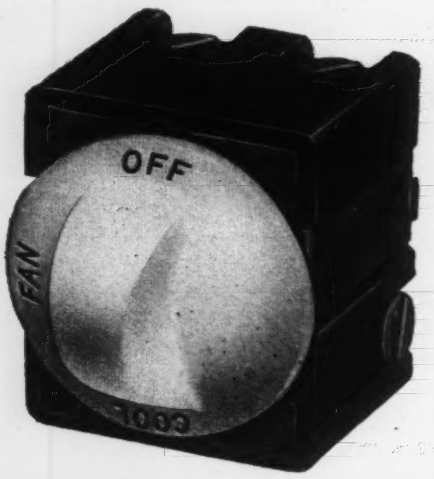


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tion, air capacity, fuel-air ratios, carburetors, spark ignition, and cooling are each treated in separate chapters. Material on compression-ignition and two-stroke engines, performance, and supercharging makes up the last section of the book.

♦

**Mechanical Power Transmission Manual.** *By William A. Williams, consulting engineer; 441 pages, 5½ by 8½ inches, clothbound; published by Conover-Mast Publications Inc., New York; available from* MACHINE DESIGN, $6.00 postpaid.

Fundamental factors of acceleration, power, and work which govern the selection of proper power transmission equipment are covered in this book. Written for the designer and operating engineer, the text outlines principles upon which each type of mechanical power transmission equipment functions, its performance characteristics, its advantages, and the types of drives to which it is best adapted. Merits of various drives are discussed and comparisons drawn.

♦

**History of Strength of Materials.** *By Stephen P. Timoshenko, professor of engineering mechanics, Stanford University; 462 pages, 6 by 9 inches, clothbound; published by McGraw-Hill Book Co. Inc.; New York; available from* MACHINE DESIGN, $10.00 *postpaid.*

Written for those in the field of engineering mechanics, this book is a thorough account of the development of the science of strength of materials. Portions of the histories of the theory of elasticity and theory of structures are also included. Major contributions of prominent scientists and engineers are related in brief biographies.

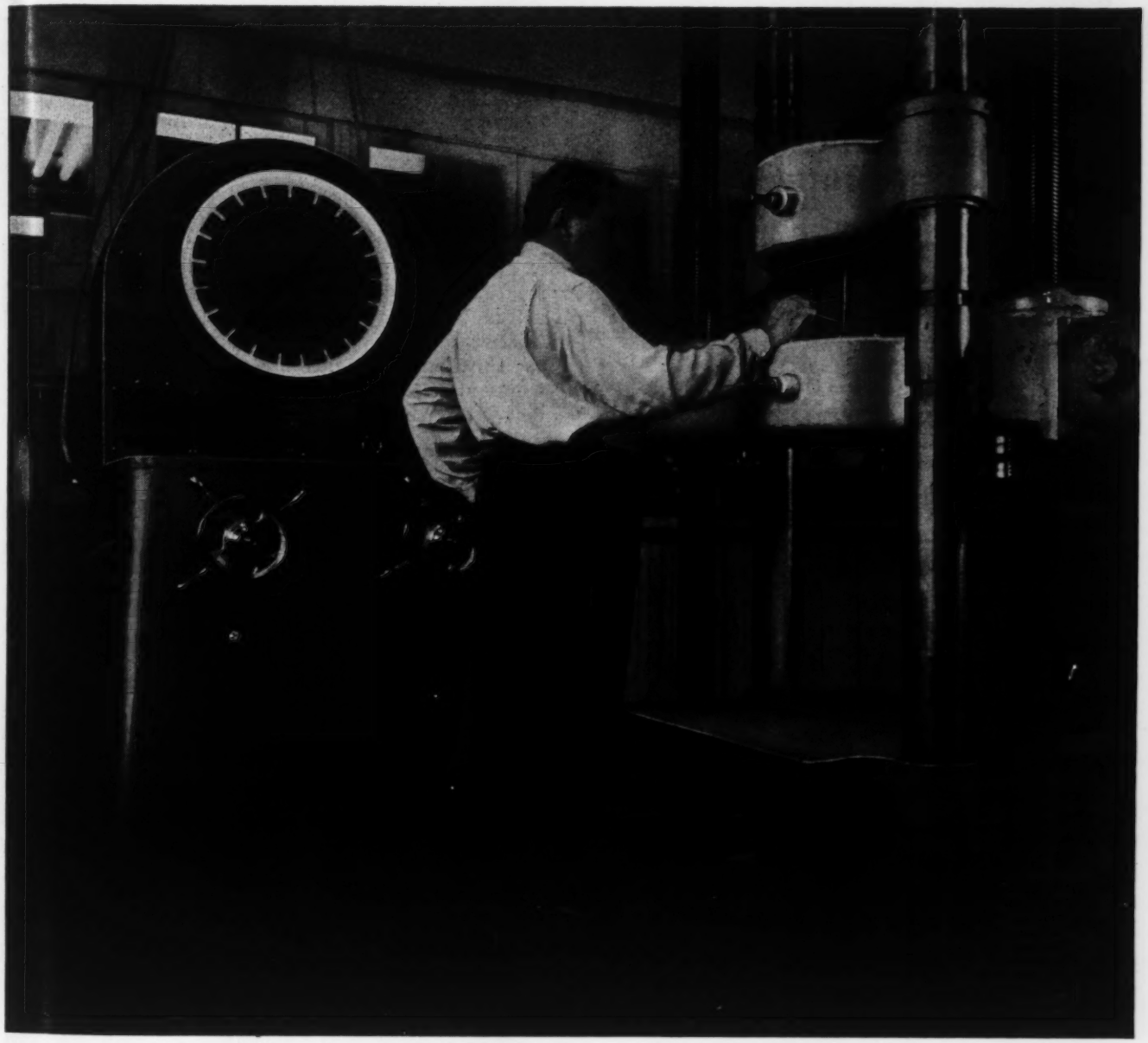
♦

**Engineering Drawing.** *By Frank Zozzora, associate professor of engineering drawing, University of Delaware; 377 pages, 8½ by 11 inches, clothbound; published by McGraw-Hill Book Co. Inc., New York; available from* MACHINE DESIGN, $5.00 *postpaid.*

This text is written for both the student and the practicing engineer. Lettering, orthographic projection, drawing instruments, geometrical constructions, dimensioning, sectioning, auxiliary views, and assembly drawing are among the subjects covered. Over 700 illustrations are included throughout the book. A detailed appendix is included containing tables and design information on commonly used fastening devices, classifications of fits, and other related matters.

♦

**Introduction to the Theory of Plasticity for Engineers.** *By Oscar Hoffman, professor of engineering mechanics, Case Institute of Technology, and George Sachs, research*



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## The Engineer's Library

*professor, Syracuse University; 290 pages, 6 by 9 inches, clothbound; published by McGraw-Hill Book Co. Inc., New York; available from* MACHINE DESIGN, *$6.50 postpaid.*

Behavior of ductile metals beyond the elastic range is treated in this text along with major engineering applications of the theory of plasticity. Basic theories of post-elastic characteristics are covered in the first part including stress and strain and their relationships. The second part of the book deals with problems in plastic flow of ideally plastic materials. In the third part problems in plastic flow of strain-hardening materials are discussed. The final section is devoted to metal-forming processes.

## Association Publications

**Bibliography of Resistance Welding.** *RWMA Bulletin No. 17; 56 pages, 8½ by 11 inches, paper cover; available from Headquarters of the Resistance Welder Manufacturers Association, 1900 Arch St., Philadelphia 3, Pa., $1.25 per copy.*

This bibliography contains a comprehensive record of articles on all phases of resistance welding that have been published in the United States since 1946. Some articles before that date have also been included because of their continued value and importance.

•

**1953 Engineering College Research Council Review.** *342 pages, 6 by 9 inches, paperbound; available from Engineering College Research Council, 103 Mechanical Engineering Bldg., Pennsylvania State College, State College, Pa., $2.50 per copy.*

Published by the Engineering College Research Council of the American Society for Engineering Education, this book is a review of approximately 7500 current research projects as reported by 103 engineering schools in the United States. Current member institutions of ECRC are included along with names of administrative officials and research policies for each school.

## New Standards

**ASTM Standards on Copper and Copper Alloys.** *556 pages, 6 by 9 inches, paper or clothbound; available from the American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa.; $5.00 paperbound, $5.65 clothbound.*

This 1953 edition includes 115 ASTM standards covering 102 materials specifications and nine test methods. Contents include copper, copper alloys, copper-covered conductors, and various other forms of copper, such as sand and die castings. Slab zinc, pig lead,

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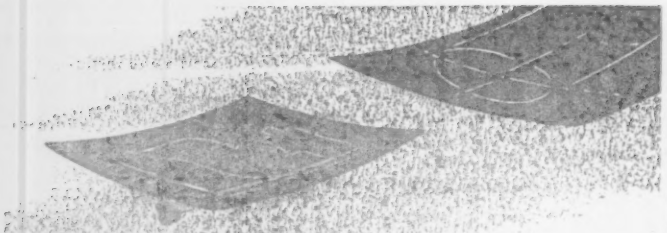

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## The Engineer's Library

nickel, phosphor, silicon, electrolytic cathode copper, and other materials are treated in the nonferrous specifications.

♦

**ASTM Standards on Plastics.** 708 *pages, 6 by 9 inches, paperbound; available from the American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa.;* $5.25.

Specifications, definitions, nomenclature and tests for commercial plastics are the subject material for the 135 standards that make up this volume. A wide range of molding compounds and materials made from these compounds are covered. Methods to determine strength, hardness, thermal and optical properties of plastic materials along with miscellaneous subjects are included.

♦

**Small Solid Rivets.** *ASA B18.1-1953; 11 pages, 8½ by 11 inches, paperbound; available from American Society of Mechanical Engineers, 29 W. 39th St., New York 18, N. Y.;* $1.00 *per copy.*

Sizes, proportions and dimensions, fillet radii, tolerances, ductility and hardness tests, and finishes of small solid rivets are covered in this report. Standard types included are flat head, countersunk head, button head, pan head, truss head, tinners', coopers', and belt rivets.

## Manufacturers' Publications

**Handbook of Noise Measurement.** 124 *pages, 8½ by 11 inches, paperbound; available from General Radio Co., 275 Massachusetts Ave., Cambridge 39, Mass.;* $1.00 *postpaid.*

Measurement of noise and other sounds transmitted by an air medium—including definitions, standards, measuring equipment, measurement procedures, and interpretation of results—are covered in this publication. Tables to convert decibels to power and pressure ratios and vice-versa are also provided.

## Government Publications

**NACA Technical Series.** *Each publication is 8 by 10½ inches, paperbound, side-stapled; copies available from National Advisory Committee for Aeronautics, 1924 F St. N.W., Washington 25, D. C.*

The following Technical Notes are available:

2956. **Creep-Buckling Analysis of Rectangular-Section Columns**—24 pages.

2963. **Effect of Variation in Rivet Strength on the Average Stress at Maximum Load for Aluminum-Alloy, Z-stiffened Compression Panels That Fail by Local Buckling**—17 pages.

2973. **Effect of Prestraining on Recrystallization Temperature and Mechanical Properties of Commercial, Sintered, Wrought Molybdenum**—25 pages.

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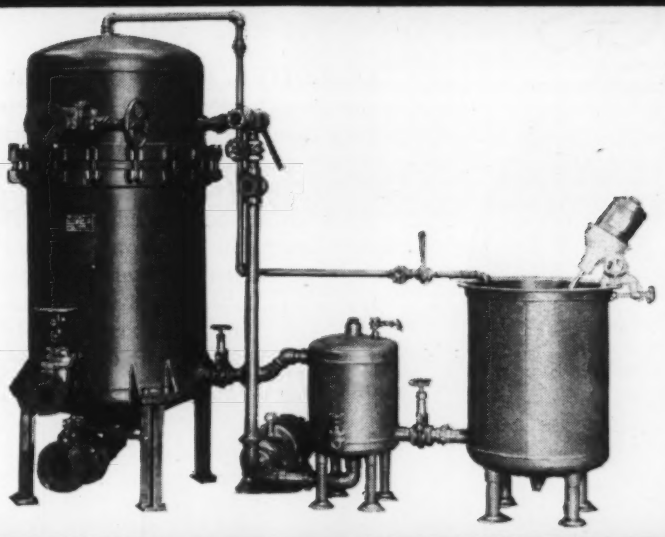

## another successful product design with piping equipment by CRANE

Keeping swimming pool operators happy—and swimmers healthy—is big business with R. P. Adams Co., Inc., of Buffalo, N. Y. For theirs is an outstanding and popular line of water filters such as type WFF shown above.

In keeping with sound basic design, Adams' engineers choose equipment of utmost dependability and low-cost maintenance. In piping materials, for example, they prefer Crane because of the traditional better quality and thrifty performance of Crane valves and fittings.

Most design engineers know they need but turn to their Crane catalog to make piping specifications come easier. It's their best guide to the biggest selection of valves and fittings for all applications . . . their best source of complete specification data . . . sizes and dimensions, temperature and pressure ratings, materials and construction. And more important, the Crane name on piping equipment puts an added mark of quality and value on product design.

**Crane Wedge Disc Clamp Gate Valve . . . extra strong, extremely compact. Clamp design is ideal where frequent cleanout is essential. Bonnet assembly and disc lift out—body stays in the line. O. S. & Y., inside screw, and quick-opening patterns, all-iron or brass trimmed. Screwed or Flanged ends. Sizes up to 4 in. Working pressures up to 150 p.s.i. saturated steam, 225 p.s.i. cold service.**

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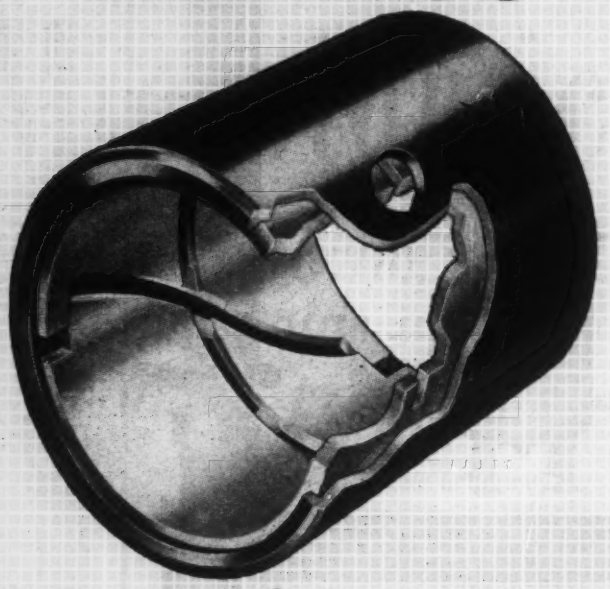

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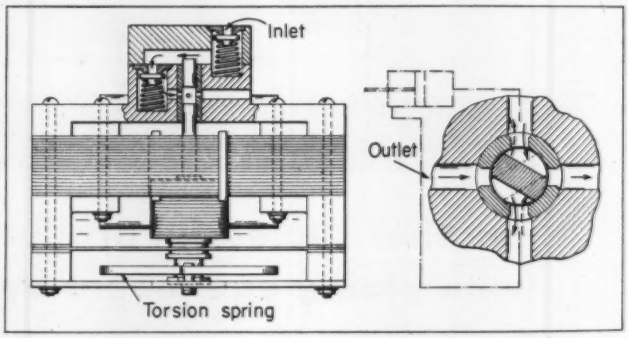
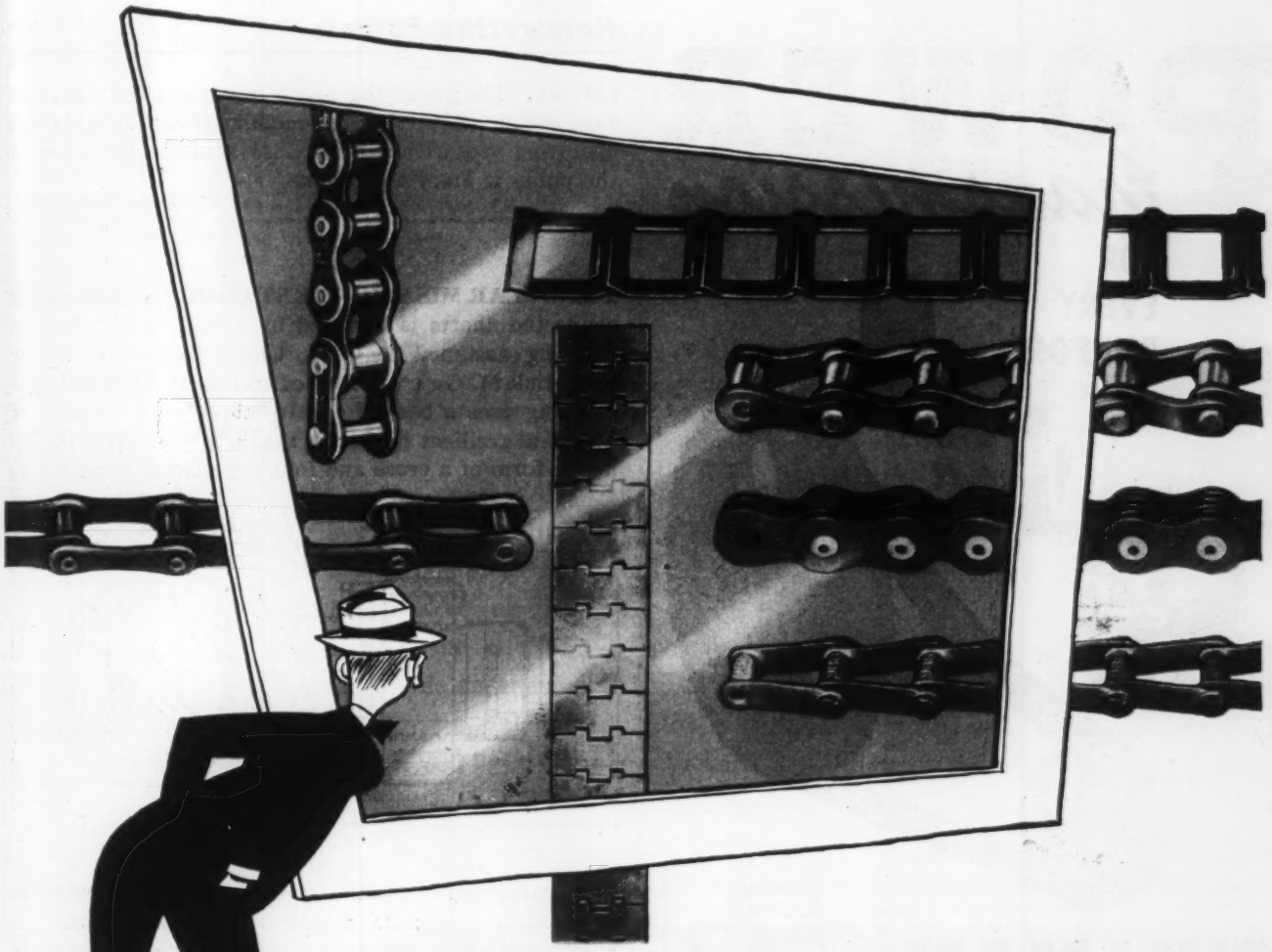
# NOTEWORTHY Patents

**SELECTIVE FLOW CONTROL** for hydraulic systems is afforded by a novel electromagnetic pump which incorporates a built-in four-way valve and generates pressure by vibration. Detailed in patent 2,627,811, the pump designed by Anthony Van Ryan may be direct connected to a double-acting cylinder or other hydraulic components operating under similar flow requirements, eliminating the need for auxiliary valving usually employed. Pumping action is produced by a modified shaded-pole ac motor having a vertical rotor mounted on a leaf spring; cyclic variations in the alternating current impart a continual




vibratory reciprocating motion to the upper rotor shaft which extends into a fluid pressure chamber located at the top of the unit. Direction of fluid flow is controlled through a reduced section in the upper shaft which acts as a plug valve in a clever four-way porting arrangement. Valve position is a function of the voltage impressed on the rotor which acts against the limiting effect of a torsion spring attached to the bottom of the shaft. Under normal voltage no flow occurs; below normal voltage permits flow in one direction; and above normal voltage reverses the flow. The patent has been assigned to McGraw Electric Co.

**VARIABLE PRESSURE DEMANDS** in hydraulic or pneumatic systems can be accurately met with a novel built-up rotary pump design assigned to Ellipse Corp. under patent 2,628,568. A wide range of output pressures is achieved through the use of interchangeable disk-shaped pumping units which can be "stacked" in series arrangements between two endplates to provide different multistage pumping combinations. Pumping action of each unit is produced by a sliding-vane rotor driven in an elliptical stator opening by a splined drive shaft. Separator plates mounted between the units guide the fluid flow. Positioning and locking of the units is accomplished by tiebolts which extend the length of the assembly, facilitating assembly and main-



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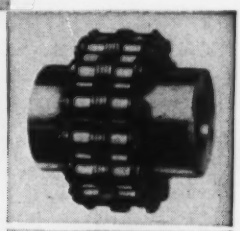

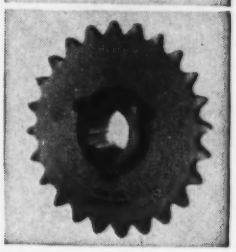

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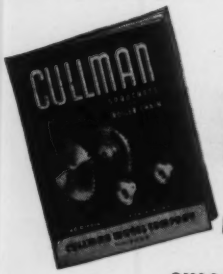


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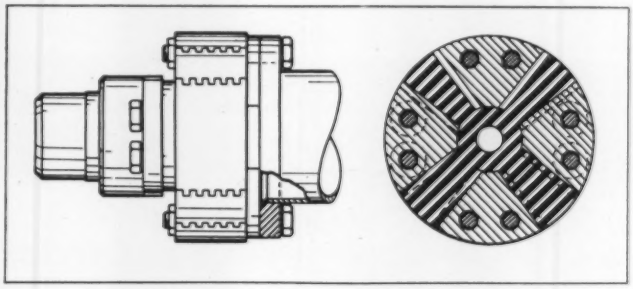
tenance. Design of the pump minimizes the effect of vane wear. Several rotor modifications for different operating requirements are also shown. Inventor of the pump is Marvin L. Rhine.

**ANGULAR MISALIGNMENT COMPENSATION** for connected shafts is afforded by a lightweight flexible coupling assigned to U. S. Universal Joints Co. by Frederick M. Guy. Described in patent 2,629,991, the coupling uses a bonded construction which consists of a central resilient rubber or synthetic section make up in the form of a cross and four pie-shaped, hollow aluminum segments. Compact and light, the design of the coupling permits maximum freedom of the resilient section to accommodate angular displacements of the connected members. Interlocking teeth on the metallic and rubber elements facilitate bonding and the coupling construction simplifies assembly and installation.



**EQUALIZED STRESS DISTRIBUTION** in a spoke construction for built-up belt pulleys increases load capacity over conventional types. Applicable to all types of materials, the pulley construction described in patent 2,631,461 employs a special socket joint at the rim, reinforced by a riveted plate, to distribute the forces imposed by belt loads. Leverage action transmits abnormal forces to the center of the pulley, preventing damage to the rim. Inventor is John Henry Duxbury, Manchester, England.

**AIR LUBRICATION** is utilized for high speed operation in a novel oilless sleeve bearing described in patent 2,627,443. Designed for electric motor applications, the bearing employs in combination a stainless steel shaft and a slightly oversize graphitized carbon sleeve. With a relative surface speed in excess of 1200 feet per minute and a loading of approximately 1/6 psi, the ambient air film acts as a fluid wedge to separate the rotating surfaces. Successful operation without oil in a motor running at 21,000 rpm for 500 hours has been achieved. Boundary lubrication, to prevent scoring during overload, is provided by the

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